(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
10 May 2001 (10.05.2001)

PCT

(10) International Publication Number
WO 01/33666 A1

(51) International Patent Classification[7]: H01Q 1/36, 1/38, 1/24

(21) International Application Number: PCT/US00/29288

(22) International Filing Date: 24 October 2000 (24.10.2000)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
60/162,148 29 October 1999 (29.10.1999) US

(71) Applicant *(for all designated States except US)*: MOTIENT SERVICES INC. [US/US]; 10802 Parkridge Boulevard, Reston, VA 20191 (US).

(72) Inventors; and
(75) Inventors/Applicants *(for US only)*: **MCGOWAN, Curt** [US/US]; 10802 Parkridge Boulevard, Reston, VA 20191 (US). **OGLESBY, Stephen, M.** [US/US]; 10802 Parkridge Boulevard, Reston, VA 20191 (US). **WEST, James, B.** [US/US]; 10802 Parkridge Boulevard, Reston, VA 20191 (US). **FLATEN, Glenn, A.** [US/US]; 10802 Parkridge Boulevard, Reston, VA 20191 (US).

(74) Agents: **DONNER, Irah, H.** et al.; Hale and Dorr LLP, 1455 Pennsylvania Avenue, N.W., Washington, DC 20004 (US).

(81) Designated States *(national)*: AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CR, CZ, DE, DK, DM, DZ, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, TZ, UA, UG, US, UZ, VN, YU, ZA, ZW.

(84) Designated States *(regional)*: ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).

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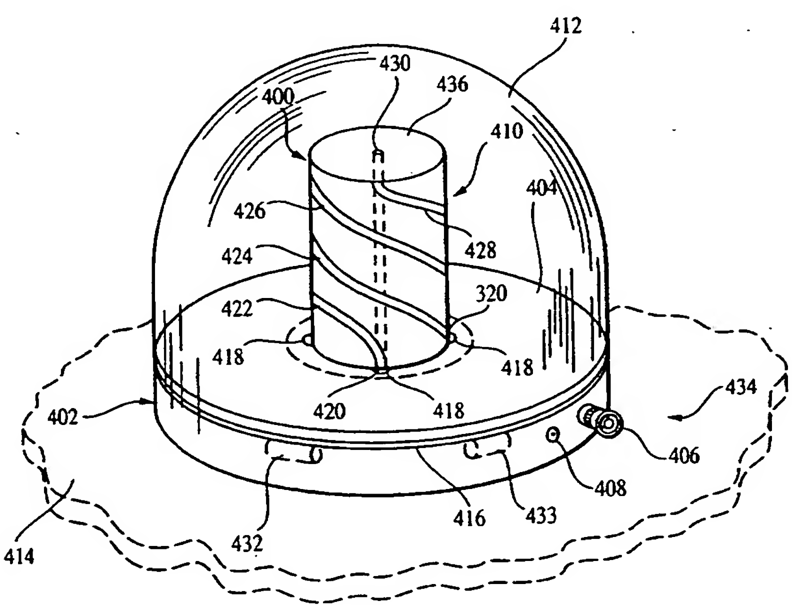
(54) Title: **DUAL-MODE SATELLITE AND TERRESTRIAL ANTENNA**



(57) Abstract: A dual mode antenna assembly (400) has a quadrifilar antenna (410) assembly for satellite communications and a monopole antenna for terrestrial communications. The satellite antenna is positioned concentrically around and external to the terrestrial antenna (430), and has first (422), second (424), third (426) and fourth (428) antenna elements. An impedance matching network makes the impedance of the terrestrial antenna (430) located inside the quadrifilar antenna (410) have essentially the same impedance as that of an isolated monopole not surrounded by the quadrifilar antenna (410).

WO 01/33666 A1

Published:

- *With international search report.*
- *With amended claims.*

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

DUAL-MODE SATELLITE AND TERRESTRIAL ANTENNA

RELATED APPLICATION

This application claims priority from U.S. provisional application serial number 60/162,148 filed on October 29, 1999 and entitled "Dual-Mode Satellite Terrestrial Antenna", the details of which are hereby incorporated by reference.

DESCRIPTION

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates generally to a multimode antenna assembly and, more particularly, to a multimode antenna assembly that incorporates a satellite communications radiating element positioned concentrically around and external to a terrestrial communications radiating element.

Background Description

Mobile communications systems are known in the art for providing a communications link between a mobile vehicle such as an automobile, truck, trailer, airplane or the like, and a stationary base or another mobile vehicle. A communications link, as used in the present application, is defined, but not limited to voice, data, facsimile, or video transmission or the like. Some such known systems utilize local radio dispatched vehicles (e.g., taxis, police, deliveries, repair services, or the like), ham or amateur radio, Citizens Band (CB) Radio, commercial transmitters, cellular receivers and the like. Such systems are known as terrestrial systems.

Terrestrial systems can be linked via a network to provide greater range and/or service. Terrestrial transmission generally involves strong received signals at the mobile terminal and at the base stations, and short delays owing to relatively short propagation distances. These factors simplify receiver design and reduce mobile transmit power required. In addition, the cost of terrestrial transmission, on a per mobile terminal basis, is typically lower than that of satellite transmission. One such terrestrial transmission network, shown in Figure 1, is the Motient^{SM} network 100. Networks of this nature provide secure, portable, two-way communication between handheld wireless data terminals, mobile data terminals, and their respective host computers.

The network 100 is a terrestrial wireless two-way data network that allows subscriber units such as an intelligent terminal or computing device 102, handheld device 104, or other communications

device 106 to communicate with their respective host computer 108 and each other without a phone line connection. Subscriber units 102, 104, 106, therefore, typically have a radio frequency (RF) modem for sending and receiving signals.

The network 100 has over 1750 base stations (110) providing service to cities and towns throughout the United States, Puerto Rico, and U.S. Virgin Islands. Each base station 110 covers a radius of approximately 15-20 miles. The base stations 110 are radio frequency towers that transmit or receive radio signals between subscriber units 102, 104, 106 and the Radio Frequency/Network Control Processors (RF/NCPs) 112. Base stations 110 transmit and receive radio signals, preferably using a narrow band FM transmitter and receiver operating in the 800 MHz frequency band. There are separate frequencies for the transmit path and the receive path; together these two frequencies represent a full duplex channel that normally transmits data at 4800 bps in both directions. In operation, for a message "inbound" to the network 100 from a subscriber unit 102, 104, 106, the signal is "heard" by the base stations 110 and sent over a phone line 116 to a RF/NCP 112. The network 100 employs an automated roaming capability that allows the free movement of subscriber units 102, 104, 106 between cities and between multiple channels within a given city. This capability allows the subscriber units 102, 104, 106 to freely move (roam) across the country and take advantage of all the network 100 services that are available in every locale.

The RF/NCPs 112 are high-speed computers that interconnect multiple base stations 110 with the ARDIS® Connect Engine(s) (ACEs) 114. A number of RF/NCPs 112 are located together serving a particular geographical area, each being connected by high speed digital phone service to one of the ACEs 114, which route messages to a destination such as a customer host computer 108 that is directly connected to the network 100 by, for example, a leased telephone line or a value added network. RF/NCPs 112 pass information relating to source, destination and length of each message to an ACE 114 that enables the network 100 to do network analysis of traffic density in, for example, each city. An ACE 114, in turn, passes information back to a RF/NCP 112 concerning whether the subscriber unit 102, 104, 106 is properly registered to the network 100 and, if so, what level of service of provided to the respective subscriber 102, 104, 106. The RF/NCPs also help manage the roaming capability of the network 100. Subscriber units 102, 104, 106 can automatically move (roam) between any of the network 100 frequencies on either of the two protocols (MDC 4800 and RD-LAP 19.2), or between any of the configured network 100 layers that have been configured for in-building or on-street usage.

The ACEs 114 are general purpose computers that act as the heart of the network 100. The ACEs 114 route messages to the proper destination, store subscribe registration information including entitlement, and perform accounting and billing functions. The ACEs 114 also serve as a point of connectivity to customer host computers 108, perform protocol conversion, and perform network 100 troubleshooting and test functions. A plurality of ACEs 114 are interconnected through dedicated leased lines, with alternate paths available from each switch as a contingency measure against line interruptions.

The wireline network 116 provides communication between the customer host computers 108, the ACEs 114, the RF/NCPs 112, and the base stations 110. The wireline network 116 is equipped with sophisticated communications equipment that relays customer messages. This equipment includes intelligent multiplexers, leased telephone circuits, high-speed modems or digital service units, and modems for both RF/NCP 112 and customer host computer 108 connectivity.

Satellite relay mobile communications systems are also known, such as that disclosed in U.S. Patent No. 5,594,461 to O'Neill Jr., and that disclosed in U.S. Patent No. 5,485,170 to McCarrick, each herein incorporated by reference in its respective entirety. Satellite transmission offers the advantage of wide coverage area owing to the large footprints of its beams. However, some of its major disadvantages are weak received signals, both on the ground and at the satellite, and long transmission delays because of great propagation distances. In addition, satellite network infrastructure costs tend to be higher than their terrestrial counterparts.

The O'Neill Jr. assembly relates particularly to a satellite relay mobile communications system in which a great number of mobile earth stations are expected to communicate via a single satellite relay station to an earth base station. This assembly provides a quadrature matching network for a quadrifilar helix antenna, wherein the network is compact and conveniently located adjacent an antenna element. The O'Neill Jr. invention is embodied in a quadrature matching network of transmission line transformer elements which couples a quadrifilar helix antenna to transmit or receive signal shaping circuits of a radio (the term radio, pertains generally to either a receiver or a transmitter, or to a transceiver.) The quadrifilar helix has first, second, third and fourth antenna elements disposed in a 90 degree phase relationship with respect to a nominal wavelength of an RF signal in the microwave range. The network comprises first and second transmission line transformer elements coupling the second antenna element to the first antenna element and the fourth antenna element to the third antenna element, respectively. The first and second transmission line transformer elements have respective impedances which are matched to the antenna impedance of their respective antenna element. The first and second transmission line transformer elements each have a length of quarterwave of the receive signal. A third transmission line transformer element couples the third and fourth transformer element, has a length of a halfwave of the receive signal, and has an impedance which is matched to a combined effective impedance of the third and fourth antenna elements. The combined and phase corrected signal is coupled through an output quarterwave transmission line transformer to a signal terminal of a microwave transceiver.

In reference to the O'Neill Jr. patent, Figure 2 shows a quadrifilar microwave antenna assembly 210. The antenna assembly 210 extends from a circular pan-like sturdy mounting base 211, preferably an aluminum casting, and which also serves as a bottom housing or cover and RF shield. A quadrifilar helical antenna ("antenna") 212 extends centrally above a circular, rigid RF shield 214, which is preferably a 1/4-inch thick aluminum disc. The shield 214 also serves as a convenient heat sink and

dissipator for RF power transistors while the antenna 212 is operating in a transmit mode. The shield 214 may be mounted to, and rigidly supported by, the mounting base 211. A parabolic or hemispherical cover 215 (i.e., a radome cover) of preferably a microwave transparent material, such as plastic or fiberglass material, encases and protects the antenna 212. The mounting base 211 may be mounted to a cab of a truck, train or other transportation instrumentality, where the numeral 216 designates a portion of a roof line of a vehicle, in accordance with a preferred use of the antenna assembly 210 as part of a mobile, earth orbiting satellite communications system.

Further in reference to Figure 2, a dielectric substrate 217 is preferably firmly mounted or adhesively attached to the shield 214 opposite the side from which the antenna 212 extends. The shield 214 has insulated apertures 218 with respective axially disposed lead through terminations 219 of four quadrifilar antenna elements 221, 222, 223 and 224. The terminations 219 are electrically short coaxial extensions of the respective antenna elements 221, 222, 223 and 224 to preserve the preferred characteristic 50 ohm (Ω) antenna impedance. In a preferred implementation of the antenna 212, the apertures 218 are arranged in a square pattern in the shield 214. From the terminations 219, the antenna elements 221, 222, 223 and 224 wind spirally about a cylindrical dielectric core 225.

As shown in Figure 3, the McCarrick assembly provides a multi-turn quadrifilar helix antenna fed in phase rotation at its base. The antenna of the McCarrick disclosure provides for an adjustment of the helix elements, causing beam scanning in the elevation plane. This quadrifilar helical antenna is omni-directional in azimuth, making the antenna suitable for mobile vehicular antenna accessing stationary satellites.

More specifically, the McCarrick assembly comprises a multi-turn bifilar helix antenna ("antenna") using a mechanical design which permits the pitch and diameter of helix elements 305 and 306 to be adjustable. This mechanical adjustment elicits an electrical response in the radiation characteristics of the antenna which permits beam steering of the radiation pattern in the elevation plane. The antenna is capable of scanning its main radiation beam from 20 degrees to 60 degrees in elevation while maintaining relatively omni-directional coverage in azimuth.

The antenna is designed to mount to a detachable base located on the vehicle skin (e.g., trunk, fender, roof, or the like). Its scanned radiation angle is set manually by the vehicle operator with the relatively simple adjustment of knurled sleeve 322 at base 317 of the antenna.

Bifilar helix 304 comprises two helix elements 305 and 306 separated 180 degrees apart, but sharing a common axis. In the preferred embodiment, helix elements 305 and 306 have conductors made of a highly conductive material, such as copper. Helix elements 305 and 306 serve as the radiating portion of the antenna. Helix 304 has distal end 309 and proximal end 310. In general, distal end 309 of the vertically mounted antenna is the end which is furthest from the ground plane formed by the vehicle skin. The antenna is fed at distal end 309 with a balanced assembly comprising coaxial cable section 311 terminating in balun 314. This distal feed technique is sometimes referred to as the backfire mode.

Helix elements 305 and 306 are formed by being wound around a constant diameter tube to form a uniform helix. The angle of pitch of helix 304 is determined by the number of helix turns for a given axial length. Pitch in unit length is defined as the axial length required for the helix to make one complete turn about its axis. When helix elements 305 and 306 are wound 180 degrees apart as suggested above, a criss-cross effect of the elements is observed when the structure is viewed from the side.

The spacing (helix diameter) and angle of pitch of helix 304 determines the polarization and radiation characteristics of the antenna. A bifilar helix with left-handed helices (ascending counter-clockwise as viewed from the bottom) radiates a right-hand circularly-polarized (RHCP) wave which is relatively omni-directional in azimuth. If the pitch angle and or the diameter of helix 304 is increased from an initial reference point, the radiation in elevation is scanned towards the horizon. In the present invention, the element pitch angle and helix diameter are adjusted by varying the number of helix turns for a fixed axial length.

In one embodiment, helix elements 305 and 306 are made from 300 ohm twin lead line commonly used in FM receivers and some television leads. One of the conducting leads is removed from the polypropylene sheathing of each of helix elements 305 and 306, while the remaining lead serves as the radiating element. Thus, helix elements 305 and 306 each contain only one wire. Polypropylene is preferred because it readily takes a helix shape when wrapped around a metal tube (not shown) and heated with a hot air gun. Other heating techniques can also be used including heating the metal tube itself. Helical elements 305 and 306 may be formed from two 37 inch lengths of 300 Ohm twin lead line suitably modified as discussed above by stripping one of the leads from the sheathing. When wound six and one-half times around a 5/8 inch diameter tube, helical elements 305 and 306 are formed at an axial length of about 31 inches.

Formed helix elements 305 and 306 are placed over a 31 inch long 3/8 inch diameter hollow supporting tube 312 which may be made of any fairly robust insulating material such as phenolic resin. Supporting tube 312 is centrally located within a 32 inch long outer sheath 313 which is one inch in diameter. Outer sheath 313 also may be formed of any robust insulating material such as polycarbonate and serves to provide environmental sealing of the antenna assembly. Coaxial cable 311 is fed through the center of supporting tube 312 and is terminated at the distal end 309 at balun 314. Coaxial cable 311 may be formed from a UT141 semi rigid coaxial line.

Balun 314 comprises a hollow 3/16 inch diameter brass tube with two feed screws 323 and 324 located 180 degrees apart. The wire portions of helix elements 305 and 306 are secured to the termination of balun 314, one on each side, by feed screws 323 and 324. Proximal end 310 of coaxial line 311 is terminated by connector 316 which may be press fitted into base 317 of the antenna. Balun 314 serves to maintain a relative phase difference of 180 degrees between the radiating elements for the required frequency bands.

In an alternative embodiment, balun 314 comprises a hollow 3/16 inch diameter slotted brass tube with two slots in the tube located 180 degrees apart. The slots are 0.124 inches wide by 1.85 inches long. The wire portions of helix elements 305 and 306 are soldered to the termination of balun 314, one on each side, separated by the slots.

Support tube 312 is captured at distal end 309 by end cap 318 set into distal end 309 of outer sheath 313 so as to prevent support tube 312 from rotating. End cap 318 is secured to distal end 309 of outer sheath 313 by glue, screws, threading, press fit, or the like.

Proximal end 310 of support tube 312 is movably attached to inner rotatable sleeve 319 by threaded member 326. Threaded member 326 may be, for example, a 1/4-20 threaded stainless steel sleeve. Spring 325 is installed at the point of rotation between support tube 312 and inner rotatable sleeve 319 to prevent undesired relative movement between inner rotatable sleeve 319 and support tube 312. Spring 325 may be made of, for example, stainless steel. Inner rotatable sleeve 319 is held in place by two set screws 321 within knurled adjustment outer sleeve 322. Inner sleeve 319 and outer sleeve 322 are located within base 317 which supports outer sleeve 313 and connector 316. The two grounded ends of helix elements 305 and 306 are attached to rotating set screws 321, creating a mechanism for changing helix pitch. Access to knurled outer sleeve 322 is made by machining two window slots (not shown) in the base 317. Base 317, inner sleeve 319 and outer sleeve 321 may be made from any suitable insulating plastic material with requisite strength requirements, such as DELRIN® plastic.

Helix 304, preferably made of polypropylene, has the desirous property of maintaining a uniform pitch along its axial length, even when one end is rotated with respect to the other. By fixing proximal end 309 of helix elements 305 and 306 from rotation to balun 314 and attaching proximal ends 310 of helix elements 305 and 306 to rotatable outer sleeve 322, an elevation steerable antenna with fixed height and adjustable pitch is achieved.

In operation, the operator loosens knurled locking bolt 303 (held firm by spring 320) and twists knurled outer sleeve 321 through the two window slots (not shown) to adjust the axial pitch of antenna 300. In its initial position, helix elements 305 and 306 make approximately six and one-half turns within the axial length of the antenna. This allows for coverage within 20 degrees above the horizon. In the other extreme, helix elements 305 and 306 make just under ten complete turns, allowing for coverage up to 60 degrees above the horizon. A mechanical limiter (not shown) and elevation angle indicator (not shown) are used to prevent the user from forcing the helix elements beyond their six and one-half and ten turn limits and to simplify the process for optimizing the antenna for elevation coverage. The operator's choice of elevation angle can be determined from the latitude where the vehicle is located, or can be positioned with the aid of a standard electronic antenna peaking device.

Functional Considerations

Functional considerations which seek to minimize size and shape of mobile earth antennas (both terrestrial and satellite systems) are also inherently related to system cost reduction. The size of antenna assemblies for mobile transceiver units is considered a source of possible problems because of limited mounting space for such antenna assemblies on mobile equipment, such as trucks or automobiles. The operation of the mobile transceiver units presupposes an exposure of the respective antenna assemblies to the position of the satellite relay, desirably omnidirectional quality, and further, from a practical standpoint, a practical shape and size realization to permit an antenna assembly to be mounted on the roof of a truck, cab, or a similar sky accessible location of a vehicle. In addition, a compact size of a desirable antenna assembly will further reduce a wind resistance profile at the top of a moving vehicle. Antennas and corresponding antenna coupling circuits of the mobile earth stations are consequently under constraint to be efficient from both functional and cost standpoints.

A need exists for an integrated antenna that can provide parallel use of the terrestrial and satellite network while conforming with the aforementioned constraints. The present invention fulfills this need by providing a multimode antenna assembly having both satellite and terrestrial communications elements, where the satellite communications element is positioned concentrically around and external to the satellite communications element.

SUMMARY OF THE INVENTION

It is a feature and advantage of the present invention to provide an antenna assembly that incorporates both a satellite communication radiating element and a terrestrial communication radiating element, forming a dual mode antenna assembly of compact size.

It is a further feature and advantage of the present invention to provide a dual mode antenna assembly that is efficient from both functional and cost standpoints.

It is another feature and advantage of the present invention to provide a dual mode antenna assembly that is compatible with existing antenna devices.

It is another feature and advantage of the present invention to provide a dual mode antenna assembly that is manageable and practical in its implementation.

It is another feature and advantage of the present invention to provide a dual mode antenna assembly that does not require significant additional hardware in its implementation.

It is another feature and advantage of the present invention to provide an dual mode antenna assembly that uses and/or adapts existing hardware to achieve desired effects, such as being detachable.

To achieve these features and advantages, a dual mode antenna assembly is provided that, in a preferred embodiment, comprises both a satellite and a terrestrial communications element, where the satellite communications element is positioned concentrically and external to the terrestrial element. The satellite element is preferably a quadrifilar helical antenna, and the terrestrial antenna is preferably a

monopole. The dual mode antenna assembly also comprises an impedance matching network that compensates for the impedance loading effect of the quadrifilar helical antenna on the monopole antenna. The impedance matching network makes the impedance of the terrestrial monopole located inside the quadrifilar helix have essentially the same impedance as that of an isolated (i.e., single) monopole not surrounded by a quadrifilar helical antenna.

There has thus been outlined, rather broadly, the more important features of the invention in order that the detailed description thereof that follows may be better understood, and in order that the present contribution to the art may be better appreciated. There are, of course, additional features of the invention that will be described hereinafter and which will form the subject matter of the claims appended hereto.

In this respect, before explaining at least one embodiment of the invention in detail, it is to be understood that the invention is not limited in its application to the details of construction and to the arrangements of the components set forth in the following description or illustrated in the drawings. The invention is capable of other embodiments and of being practiced and carried out in various ways. Also, it is to be understood that the phraseology and terminology employed herein are for the purpose of description and should not be regarded as limiting.

As such, those skilled in the art will appreciate that the conception, upon which this disclosure is based, may readily be utilized as a basis for the designing of other structures, methods and systems for carrying out the several purposes of the present invention. It is important, therefore, that the claims be regarded as including such equivalent constructions insofar as they do not depart from the spirit and scope of the present invention.

Further, the purpose of the foregoing abstract is to enable the U.S. Patent and Trademark Office and the public generally, and especially the scientists, engineers and practitioners in the art who are not familiar with patent or legal terms or phraseology, to determine quickly from a cursory inspection the nature and essence of the technical disclosure of the application. The abstract is neither intended to define the invention of the application, which is measured by the claims, nor is it intended to be limiting as to the scope of the invention in any way.

These together with other objects of the invention, along with the various features of novelty which characterize the invention, are pointed out with particularity in the claims annexed to and forming a part of this disclosure. For a better understanding of the invention, its operating advantages and the specific objects attained by its uses, reference should be made to the accompanying drawings and descriptive matter in which there is illustrated preferred embodiments of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

The Detailed Description including the description of a preferred structure as embodying features of the invention will be best understood when read in reference to the accompanying figures wherein:

Figure 1 is a schematically simplified representation of the Motient^{SM} terrestrial communications network;

Figure 2 is a schematically simplified pictorial representation of a known microwave transmit and receive antenna assembly;

Figure 3 is a schematically simplified, alternative, known satellite antenna embodiment;

Figure 4A is a schematically simplified representation of the dual mode antenna assembly;

Figure 4B-4D are a schematically simplified representation of a side and front view of the dual mode antenna assembly, showing cable connectors;

Figure 5 is a front view having a partial cross section of the dual mode antenna assembly;

Figure 6A is a schematically simplified, exploded view of the dual mode antenna assembly;

Figure 6B is a schematically simplified, exploded view of an alternative embodiment of the dual mode antenna assembly;

Figure 6C is a schematically simplified, exploded view of an alternative embodiment of the dual mode antenna assembly;

Figure 6D is a schematically simplified, exploded view of an alternative embodiment of the dual mode antenna assembly;

Figure 6E is a schematically simplified, exploded view of an alternative embodiment of the dual mode antenna assembly;

Figure 7 shows a plot of the electrical radio frequency isolation between the terrestrial antenna and the satellite antenna, across a frequency band that covers both the terrestrial and satellite system operational bandwidths;

Figure 8A is an operationally representative impedance plot for the monopole terrestrial antenna;

Figure 8B is the impedance of the monopole terrestrial antenna with the effect of loading by the satellite quadrifilar helix antenna;

Figure 9A shows a preferred method of a simplified method of assembly of the dual mode antenna assembly;

Figure 9B shows a more detailed method of assembly of the dual mode antenna assembly; and

Figure 10 is a block diagram illustrating a wireless packet data transmission network that can utilize the dual mode antenna assembly of the present invention to communicate with mobile terrestrial vehicles.

DETAILED DESCRIPTION OF A PREFERRED EMBODIMENT OF THE INVENTION

An integrated dual mode antenna assembly is therefore disclosed that can provide parallel use of the terrestrial and satellite networks while conforming with function and cost constraints. The present invention fulfills this need by providing a dual mode antenna assembly that comprises an impedance matching network that compensates for the impedance loading effect of the quadrifilar helical antenna on the monopole antenna. The impedance matching network makes the impedance of the terrestrial monopole located inside the quadrifilar helix have essentially the same impedance as that of an isolated (i.e., single) monopole not surrounded by a quadrifilar helical antenna. In a preferred embodiment, the satellite element comprises a quadrifilar helical antenna, and the terrestrial element comprises a monopole antenna.

Figure 4A illustrates a quadrifilar helical antenna 410 (comprising antenna elements 422, 424, 426 and 428) with concentrically located terrestrial antenna 430. In a preferred embodiment, terrestrial antenna 430 is a component of a network such as an Motient^{SM} network 100. It should be understood that antennas other than a quadrifilar helical antenna 410 (e.g., a bifilar helix antenna) that preferably have a virtual electronic null in their center (to avoid being perturbed by the terrestrial antenna 430) may be utilized. Antenna assembly 400 comprises helical antenna 410 and terrestrial antenna 430, and extends from mounting base 402, and antenna mounting base 404, which also preferably serves as a RF shield. Helical antenna 410 extends centrally above antenna mounting base 404.

Mounting base 402 is preferably of aluminum casting, and also serves as a bottom housing or cover. As shown, mounting base 402 is circular or pan-like, and further comprises coaxial cable connector 406 and a SMA cable connector 408 (preferably 800 MHz). Alternatively, any other type of connection(s) may be used that connect(s) the dual-mode antenna of the present invention with the transceiver of the communication device. Mounting base 402 can be mounted to a cab of a truck, train or other transportation instrumentality as illustrated by portion of roof line 414 of such a vehicle.

Antenna mounting base 404 is preferably a circular, substantially rigid, 1/4 inch thick aluminum disc, serving as a convenient heat sink and dissipator for RF power transistors when helical antenna 410 is operating in a transmit mode. In alternative embodiments, antenna mounting base 404 may be of other suitable shapes and/or materials that principally function as an antenna base of the dual-mode antenna assembly 400 of the present invention. Antenna mounting base 404 can be mounted to, and rigidly supported by, mounting base 402. Antenna mounting base 404 has optional insulated apertures 418 which receive respective axially disposed lead through terminations 420 of antenna elements (i.e., sections) 422, 424, 426 and 428 of the integrated or composite helical antenna 410. Terminations 420 are electrically short coaxial or other extensions of respective antenna elements 422, 424, 426 and 428 that preserve the preferred characteristic 50 ohm antenna impedance or other predetermined impedance

characteristics, and also serve to mechanically secure the helical antenna 410 to the antenna mounting base 404. In a preferred implementation of helical antenna 410, apertures 418 are arranged in a square pattern in antenna mounting base 404. Apertures 418 may alternatively be arranged in other patterns such as triangular, rectangular, parallelogram, and the like, depending on the number of antenna elements. From terminations 420, antenna elements 422, 424, 426 and 428 wind spirally about cylindrical core 436. Preferably, the cylindrical core is comprised of a low-loss dielectric material with a dielectric constant as close to air as possible. A stabilizing element is preferably disposed between the helical antenna 410 and core 436. Preferably the stabilizing element is a foam-like material widely used in industry practice. It is further preferred that the foam-like material be a dielectric or substantially dielectric material. Each of the antenna elements 422, 424, 426 and 428 optionally and advantageously works against the other three, effectively setting up a field in the free air dielectric (e.g., the conical tube supporting the radiating elements). In a preferred embodiment, antenna elements 422, 424, 426 and 428 have conductors made of a highly conductive material such as copper.

Components of the amplifier and preselector assembly 432 are advantageously disposed on underside 434 of substrate 416, and are thus accessibly located to be directly coupled via a quadrature matching network (not shown) to antenna assembly 400. Of course, the components of the amplifier and preselector assembly 432 may be disposed on other areas of the multi-mode antenna. The components of the amplifier and preselector assembly 432 are coupled to terrestrial antenna 430, and the components of the amplifier and preselector assembly 433 are coupled to helical antenna 410. Other shapes of the core 436 may alternatively be used such as square, pyramidal, rectangular, triangular, and the like. However, the shape of core 436 must be cylindrical to meet INMARSAT C certification requirements. Azimuthal gain symmetry and axial ration will generally deteriorate with non-cylindrical shape.

Parabolic or hemispherical cover 412 encases and protects antenna assembly 400, and is preferably a microwave transparent material, such as plastic or fiberglass material. Parabolic or hemispherical cover 412 is also known by those skilled in the art as a radome cover or enclosure. Other suitable shapes and materials may be used for hemispherical cover 412.

In further reference to Figure 4A, optional dielectric substrate 416 is preferably firmly mounted or adhesively attached to antenna mounting base 404 opposite the side from which antenna assembly 400 extends. Other configurations of the mounting of substrate 416 may alternatively be used. Though the antenna mounting base 404 and the dielectric substrate 416 are illustrated as being circular in configuration, it should be realized that the circular shapes were chosen in support of a non-directional symmetry with respect to the terrestrial antenna 430. The circular footprint particularly facilitates mounting the parabolic or hemispherical cover 412 to the antenna assembly 400. However, the invention is not dependent upon this circular configuration and is equally applicable to antenna assemblies of various other shapes.

In reference to Figure 4B - 4D, there is shown a side view (Figure 4C) and two front views (Figures 4B and 4D) of the mounting base 402 with optional coaxial cable connector 406 and a SMA cable connector 408 (preferably 800 megahertz). Coaxial cable 406 and SMA cable connector 408 are optional in that they are chosen for identification purposes so that one cable of each type is connected to each of the helical antenna 410 and the terrestrial antenna 430. Accordingly, two SMA cable connectors 408, or two coaxial cable connectors 406 could equally be used in lieu of the coaxial cable connector 406 and a SMA cable connector 408.

Referring again to Figure 4A, coaxial cable connector 406 provides for the receive or transmit signals to be transferred via a communication line, such as a coaxial conductor between, for example, a transceiver and preselector assembly 432. SMA cable connector 408 provides for the receive or transmit signals to be transferred via a second coaxial conductor between a second transceiver and preselector assembly 433. The components of the amplifier and preselector assembly 432 are coupled to terrestrial antenna 430, and the components of the amplifier and preselector assembly 433 are coupled to helical antenna 410, as will be discussed in further detail in the discussion pertaining to Figures 6A-6E.

In reference to Figure 5, there is shown partial front and partial front cross sectional views of the antenna assembly 400. Mounting base 504 preferably serves as a convenient heat sink and dissipator for RF power transistors while antenna assembly 400 is operating in a transmit mode. A printed circuit board 502 underlying antenna mounting base 404 provides signal mix/demix of radio frequency. Circuit board 504 is preferably populated by receiver/transmitter circuitry (Rx/Tx). An O-Ring 506 is preferably placed within a groove within the mounting base 402, and a ring clamp 508 is preferably secured to the mounting base 402 and radome cover 412 to provide a substantially moisture resistant seal which protects the antennas 410, 430 from adverse weather, corrosion, etc. Other means to provide a substantially airtight seal could be used other than the O-Ring 506 and the ring clamp 508.

Electronic impedance matching preferably occurs on antenna mounting base 404 and on antenna board 504, as necessary. In a preferred embodiment, an impedance matching network compensates for the impedance loading effect of the helical antenna 410 on the terrestrial antenna 430. Specifically, the impedance matching network makes the impedance of the terrestrial antenna 410 substantially the same as essentially the same as the impedance of the same monopole antenna when it is not surrounded by a helical antenna 430. Note that the helical antenna 430 does not need to be radiating in order to affect the impedance of the terrestrial antenna 410; the physical proximity of the helical antenna 430 to the terrestrial antenna 410 will affect the impedance of the terrestrial antenna 410.

In reference to Figure 6A, there is shown an exploded view of helical antenna 410 with concentrically located terrestrial antenna 430. In a preferred embodiment, terrestrial antenna 430 operates at approximately 800 MHz, and the satellite antenna 410 operates at a frequency designated for satellite communications. The printed circuit board 502 underlying antenna mounting base 404 provides signal mix/demix of radio frequency to isolate only the desired signal to the proper antenna 410, 430.

Further, first cable, in its respective portions 604 and 624, is a signal feeding cable for helical antenna 410. Cable 604 connects to mounting base 402 via SMA cable connector 408. Similarly, second cable, in its respective portions 606 and 622, is a signal feeding cable for terrestrial antenna 430. Cable 606 connects to mounting base 402 via coaxial cable connector 406. Cables 622 and 624 may be pendant cables, integral with circuit board 502, or may form an electrical connection with terrestrial antenna 430 and satellite antenna 410, respectively, via any other suitable cable connection means known and practiced in the art.

First connection 608 is a connection to the helical antenna 410, and second connection 610 is a connection to the terrestrial antenna 430. First connection 608 and second connection 610 are proximate circuit board 504, and may be electrically connected thereto via any suitable cable connection means widely known in the art. In a preferred embodiment, circuit board 504 is populated by receiver/transmitter circuitry (Rx/Tx), and provides isolated internal trace from input cables 604 and 606 to third and fourth connectors 614 and 616, respectively, as well as the potential filtering required to isolate the preferred 800 megahertz Rx signal.. Third connection 614 and fourth connection 616 are each proximate to circuit board 504 and provide passage for cables 604 and 606, respectively. Circuit board 504 is proximate O-Ring 618, which is proximate ring clamp 620, which is proximate mounting base 402. In a preferred embodiment, circuit board 504 also contains at least the majority of the RF circuitry, as well as power amplifiers and filters. DC voltage preferably controls the state of the receiver/transmitter circuitry. The most common state of helical antenna 410 is in receive mode, which is preferably at approximately 10 volts. Transmit mode preferably occurs at approximately 24 volts, and idle mode preferably occurs at approximately 15 volts. DC voltage is provided via cables 604 and 624 to the helical antenna 410, and radio frequency signals are superimposed on the DC voltage. DC voltage also controls the receiver/transmitter switch (not shown).

Figure 6B depicts an alternative embodiment, wherein cables 622 and 624 shown in Figure 6A are combined into a single cable 626 that feeds both the helical antenna 410 and the terrestrial antenna 430. In this embodiment, as will be recognized to those skilled in the art, a diplexer, for example, can be utilized to combine cables 622 and 624 into cable 626. Similarly, a second diplexer can be used to split cable 626 into respective portions that connect to the helical antenna 410 and the terrestrial antenna 430, respectively. The receiver or transmitter signal is frequency matched to isolate the desired signal which is then sent to the proper antenna. In this embodiment, the signal is split in circuit board 504, with each of the two resulting signals then directed to the respective first cable 604 and second cable 606 (i.e., signals corresponding to the helical antenna 410 and the terrestrial antenna 430, respectively), which are housed by the third connection 614 and fourth connection 616, respectively.

Figure 6C depicts an alternate embodiment, wherein first cable 624 and second cable 622 are combined to form cable 636, which exits through single connection 628. First cable 624 and second cable 622 are again preferably combined via a diplexer. In this embodiment, cable 636 is preferably

either a coaxial cable or a SMA-type cable, which connects to either the coaxial cable connector 406 or the SMA cable connector 408. Accordingly, only one of either the coaxial cable connector 406 or the SMA cable connector 408 is required in mounting base 402.

Figure 6D depicts an alternate embodiment, wherein circuit board 504 and O-Ring 618, each shown in Figures 6A, 6B and 6C, are combined to form combined circuit board and O-Ring 632. As shown in Figure 6A, a printed circuit board 502 underlying antenna mounting base 404 provides signal mix/demix of radio frequency. First cable, in its respective portions 604 and 624, is a signal feeding cable for helical antenna 410. Similarly, second cable, in its respective portions 606 and 622, is a signal feeding cable for terrestrial antenna 430. First connection 608 is a connection to the helical antenna 410, and second connection 610 is a connection to the terrestrial antenna 430. First connection 608 and second connection 610 are proximate combined circuit board and O-Ring 632. In a preferred embodiment, combined circuit board and O-Ring 632 is populated by receiver/transmitter circuitry (Rx/Tx), and provides isolated internal trace from input cables 604 and 606 to third and fourth connectors 614 and 616, respectively, as well as the potential filtering required to isolate the preferred 800 megahertz Rx signal. Third connection 614 and fourth connection 616 are each proximate to combined circuit board and O-Ring 632, and provide passage for cables 604 and 606, respectively. Combined circuit board and O-Ring 632 is proximate ring clamp 620, which is proximate mounting base 402. In a preferred embodiment, combined circuit board and O-Ring 632 contains the majority of the RF circuitry, as well as power amplifiers and filters. DC voltage preferably controls the receiver/transmitter circuitry. The most common state of helical antenna 410 is in receive mode, which is preferably at approximately 10 volts. Transmit mode preferably occurs at approximately 24 volts, and idle mode preferably occurs at approximately 15 volts. DC voltage is provided via cables 604 and 624 to the helical antenna 410, and radio frequency signals are superimposed on the DC voltage. DC voltage also controls the receiver/transmitter switch (not shown).

Figure 6E depicts an alternate embodiment, wherein O-Ring 618 and ring clamp 620 shown in Figures 6A, 6B and 6C are combined to form combined O-Ring and ring clamp 634. Circuit board 502 underlying antenna mounting base 404 provides signal mix/demix of radio frequency. First cable, in its respective portions 604 and 624, is a signal feeding cable for helical antenna 410. Similarly, second cable, in its respective portions 606 and 622, is a signal feeding cable for terrestrial antenna 430. First connection 608 is a connection to the helical antenna 410, and second connection 610 is a connection to the terrestrial antenna 430. First connection 608 and second connection 610 are proximate circuit board 504. In a preferred embodiment, circuit board 504 is populated by receiver/transmitter circuitry (Rx/Tx), and provides isolated internal trace from input cables 604 and 606 to third and fourth connectors 614 and 616, respectively, as well as the potential filtering required to isolate the preferred 800 megahertz Rx signal for the terestrial antenna 430. Third connection 614 and fourth connection 616 are each proximate to circuit board 504 and provide passage for cables 604 and 606, respectively. Circuit board

504 is proximate combined O-Ring and ring clamp 634, which is proximate mounting base 402. In a preferred embodiment, circuit board 504 contains the majority of the RF circuitry, as well as power amplifiers and filters. DC voltage preferably controls the state of the helical antenna 410. The most common state of helical antenna 410 is in receive mode, which is preferably at approximately 10 volts. Transmit mode preferably occurs at approximately 24 volts, and idle mode preferably occurs at approximately 15 volts. DC voltage is provided via cables 604 and 624 to the helical antenna 410, and radio frequency signals are superimposed on the DC voltage. DC voltage also controls the receiver/transmitter switch (not shown).

Figure 7 shows a plot of the electrical radio frequency isolation between the terrestrial antenna 410 and the helical antenna 430, across a frequency band that covers both the terrestrial and satellite system operational bandwidths. As shown, the band edges for the terrestrial antenna 430 occur at approximately 806 MHz and 871 MHz, and the band edges for the helical antenna 410 occur at approximately at 1530 MHz and 1660 MHz. As will be recognized by those skilled in the art, the data indicate that the terrestrial antenna 430 does not load the helical antenna 410 (which is generally more sensitive than the terrestrial antenna 410).

Figure 8A shows a representative operational impedance plot for the terrestrial antenna 430. Figure 8B shows a representative operational combined impedance plot for the terrestrial antenna 430 and the helical antenna 410. As will be recognized by those skilled in the art, the second plot indicates that an impedance matching circuit, preferably obtained using either commercially available printed circuits or known circuit matching techniques, can be obtained without undue experimentation such that the impedance of the terrestrial monopole located inside the quadrifilar helix has essentially the same impedance as that of an isolated (i.e., single) monopole not surrounded by a quadrifilar helical antenna. When this is accomplished, Figure 8B will then have a plot very similar to that of Figure 8A. If desired, the impedance matching circuit can be integrated with circuit board 502.

Figure 9A shows a preferred method of assembly of the antenna assembly 400. In step 900, a mounting structure is provided. Preferably the mounting structure will be the same as or similar to that of mounting base 402 and/or antenna mounting base 404. In step 902, the helical antenna 410 and the terrestrial antenna 430 are mounted. In step 904, an impedance matching circuit is electrically connected to the helical antenna 410 and the terrestrial antenna 430 so that when they are radiating simultaneously their combined impedance is substantially equal to that of the terrestrial antenna 430 when radiating alone. In step 906, a cover is provided, preferably the same as or similar to the parabolic or hemispherical cover 412 described herein that encases and protects the antenna assembly 400.

Figure 9B shows a more detailed method of assembly of the antenna assembly 400. In step 950, an antenna mounting base is provided. Preferably the antenna mounting base will be the same as or similar to that of antenna mounting base 404. In step 952, a dielectric substrate 416 is secured to the underside of the antenna mounting base 404. The antenna mounting base preferably serves as a RF

shield, as well as a ground for this particular type of helical antenna 430 (e.g., a helical antenna 430 with open circuited, 3/4 wave length radiating elements).

In step 954 the helical antenna 410 and the terrestrial antenna 430 are mounted on antenna mounting base 404. Preferably, the combination of the apertures 418 and lead through terminations 420 of antenna elements 422, 424, 426 and 428 serve to secure the helical antenna 410 and the terrestrial antenna 430 in place. If desired, an adhesive such as a silicon adhesive, may be placed on the bottom portion of the terrestrial antenna 430 and/or the satellite antenna 410 to further secure them to the antenna mounting base 404. A foam material, preferably being dielectric or substantially dielectric, of a type widely used in industry practice is optionally disposed between the helical antenna 410 and the core 436. Preferably, the terrestrial antenna 430, when embedded within the foam material, should be substantially rigid and have minimal play.

In step 956, the circuit board 502 for RF mix/demix is attached, preferably to the antenna mounting base 404. The circuit board 502 is preferably attached on the side opposite to which the helical antenna 410 and the terrestrial antenna 430 are mounted. In step 958 cables are attached between circuit board 502 and circuit board 504, as previously discussed.

In step 960, a mounting base 402 is provided, preferably having cable connectors 406, 408, and an O-Ring slot as shown in Figure 5. In step 962, cables are attached between circuit board 504 and cable connectors 406, 408, as previously discussed. In step 964, an impedance matching circuit is electrically connected to the terrestrial antenna 430. The impedance matching circuit is preferably integrated with, or embedded into, circuit board 502. However, the impedance matching circuit may also be physically separated from circuit board 502.

In step 966, an O-Ring 506 in inserted into the O-Ring slot within mounting base 402. In step 968, the radome cover 412 is placed over the antennas 410, 430 and O-Ring 506. In step 970, the ring clamp 508 is secured to the radome enclosure 412 and mounting base 402 to protect against adverse weather, corrosion, etc.

It should be understood that the individual steps in Figures 9A and/or 9B may be performed in an order other than described. It should also be understood that, depending on a particular assembly technique, that one or more individual steps shown in Figures 9A and/or 9B may be combined into a single step.

Figure 10 is a block diagram illustrating a wireless packet data transmission network that can utilize the dual mode antenna of the present invention to communicate with, for example, mobile terrestrial vehicles. The network shown in Figure 10 is disclosed in U.S. Patent No. 5,953,319 to Dutta et al., and is incorporated herein by reference. Network 1000 is a multi-mode packet data network which includes mobile vehicle equipment 1010, base station packet switch 1020 and multiple radio frequency transmission paths (only first transmission path 1030, second transmission path 1040 and Nth transmission path 1050 are shown). Mobile vehicle data terminal equipment 1060 and fixed user data

terminal equipment 1070 are the end user equipment of this multi-mode network. The multiple radio frequency transmission paths may be proprietary, or may be leased sub-networks for use with or in the present invention to facilitate mobile communications in the manner described.

Mobile vehicle equipment 1010 is a terrestrial vehicle based device or system which facilitates communication between mobile vehicle data terminal equipment 1060, located on board the mobile vehicle, and fixed user data terminal equipment 1070, through base station packet switch 1020. Mobile vehicle equipment 1010 can be selectively coupled to any of the multiple radio frequency transmission paths for establishing a "logical" communication link with base station packet switch 1020.

Mobile vehicle equipment 1010 incorporates "intelligent" routing and control mechanisms to determine which of the radio frequency transmission paths a particular message data packet will be delivered through. Mobile vehicle data terminal equipment 1060 is coupled to mobile vehicle equipment 1010 and can be any of a variety of devices which exchange information with equipment 1010 for transmission/reception to/from fixed user data terminal equipment 1070. For example, mobile vehicle data terminal equipment 1060 can be other computer based systems, sensors and/or human interface devices.

Base station packet switch 1020 performs a routing function similar to mobile vehicle equipment 1010, but is positioned at a fixed location. Base station packet switch 1020 can be selectively coupled to any of the multiple radio frequency transmission paths for sending packet data messages to, and receiving packet data messages from, mobile vehicle equipment 1010. Base station packet switch 1020 incorporates intelligent routing and control mechanisms to control which of the multiple radio frequency transmission paths a particular packet data message will be transmitted through.

Fixed user data terminal equipment 1070 is coupled to base station packet switch 1020 and can be any of a variety of devices which exchange information with base station packet switch 1020 for transmission/reception to/from mobile vehicle data terminal equipment 1060. For example, data terminal equipment 1070 can be other computer based systems such as a management information system (MIS) and/or data terminal equipment 1070 can be human interface devices.

Radio frequency transmission paths 1030, 1040 and 1050 are typically different wide area communication sub-networks available from any of a number of service providers. The radio frequency transmission paths are therefore typically independent and self-sufficient sub-networks having no inter-network communication links between one another. There are at least two transmission paths, typically with at least one being a satellite-based sub-network and at least one being a terrestrial-based sub-network. For example, first radio frequency transmission path 1030 is provided by Motient Corporation's Inmarsat-C satellite sub-network. Here, the mobile-satellite communication sub-network utilizes geostationary satellites operating in the L-band of the radio spectrum. Second radio frequency transmission path 1040 is preferably a terrestrial based sub-network such as the one provided by the ARDIS® Special Mobile Radio (SMR) sub-network. Other transmission paths can be used in addition to

the Motient Corporation (or Inmarsat-C) sub-networks. For example, cellular phone and low earth orbit (LEO) sub-networks can be used as transmission paths in the present invention as well. Further, the sub-networks need not be wide-area in coverage. They can be specialized local area coverage networks.

As discussed above, a number of wide area mobile communication sub-networks are in operation in the United States and in other countries. As a transmission path, each sub-network has characteristics which provide certain advantages over other sub-networks. Satellite-based sub-networks have the highly desirable characteristic of ubiquitous coverage for many areas, particularly for rural areas of the North American continent. However, satellite-based sub-networks frequently experience blockages in urban coverage areas. Further, the signal strength of satellite-based sub-networks is low. Also, satellite equipment costs and data transmission costs are higher than those of their terrestrial counterparts.

As transmission paths, terrestrial-based sub-networks frequently offer practically full coverage in urban areas, the coverage area in which satellite sub-networks frequently experience blockages. Terrestrial-based sub-networks such as the Motient^{SM} network 100 can even provide in-building reception by mobile vehicle equipment 1010. Further, terrestrial-based sub-networks provide advantages over satellite-based sub-networks in that signal strength is higher, data transmission rates are typically higher, the costs of sending data messages are lower, and the costs of equipment are lower. However, while terrestrial-based sub-networks continue to grow in coverage, the coverage remains concentrated in metropolitan areas with major gaps existing in rural areas.

In network 1000, one or more of the differentiating characteristic features of coverage, signal strength, data rates, message delivery times and data costs are used as factors which allow mobile vehicle equipment 1010 and base station packet switch 1020 to select the most appropriate one of radio frequency transmission paths 1030,1040 and 1050. Realizing the complimentary nature of satellite and terrestrial-based sub-networks, the multi mode antenna assembly 400 of the present invention offers users the benefits of ubiquitous satellite coverage and the high data rates and in-building penetration capabilities of a terrestrial system. The antenna assembly 400 according to the present invention can thus be utilized in conjunction with a network 1000 such as shown in Figure 10 to achieve the respective advantages associated with each of terrestrial and satellite transmissions.

The many features and advantages of the invention are apparent from the detailed specification, and thus, it is intended by the appended claims to cover all such features and advantages of the invention which fall within the true spirit and scope of the invention. Further, since numerous modifications and variations will readily occur to those skilled in the art, it is not desired to limit the invention to the exact construction and operation illustrated and described, and accordingly, all suitable modifications and equivalents may be resorted to, falling within the scope of the invention. While the foregoing invention has been described in detail by way of illustration and example of preferred embodiments, numerous

modifications, substitutions, and alterations are possible without departing from the scope of the invention defined in the following claims.

CLAIMS

Having thus described our invention, what we claim as new and desire to secure by Letters Patent is as follows:

1. A dual mode antenna assembly for transmitting and/or receiving signals to/from a first communication device from/to a second communication device at least alternately via at least one of a terrestrial and a satellite communication system, said multimode antenna assembly comprising:

an antenna structure comprising a terrestrial element and a satellite element, said satellite element being positioned substantially concentrically around and external to said terrestrial element;

an impedance matching circuit electrically connected to the terrestrial element;

a support structure supporting said antenna structure; and

a mounting base having an upper surface and a lower surface, wherein the lower surface contacts a surface to which said multimode antenna assembly is secured or substantially secured and wherein the upper surface supports said support structure, said mounting base having at least one cable connector to receive at least one cable element that is electrically connected to the satellite element and to the terrestrial element.

2. The method of transmitting according to claim 15 wherein the satellite element is driven by a quadrature combiner/splitter circuit.

3. The dual mode antenna assembly according to claim 1 wherein the terrestrial element is a monopole antenna.

4. The dual mode antenna assembly according to claim 1 wherein said satellite element comprises a cylindrical core having four antenna elements disposed on a surface thereof.

5. The dual mode antenna assembly according to claim 4 wherein said cylindrical core comprises a substantially dielectric material.

6. The dual mode antenna assembly according to claim 4 wherein the antenna elements are helically wound and spaced at approximately ninety degrees with respect to each other.

7. The dual mode antenna assembly according to claim 6 wherein each of the antenna elements works against the other three, effectively setting up a field external to the cylindrical core.

8. The dual mode antenna assembly according to claim 6 wherein the impedance matching circuit

functions such that the impedance of the terrestrial element when located inside the satellite element has substantially the same impedance as that of an isolated terrestrial element not surrounded by the satellite element.

9. The dual mode antenna assembly according to claim 1 wherein the impedance matching circuit functions such that the impedance of the terrestrial element when located inside the satellite element has substantially the same impedance as that of an isolated terrestrial element not surrounded by the satellite element.

10. The dual mode antenna assembly according to claim 1 wherein said support structure serves as a radio frequency (RF) shield.

11. The dual mode antenna assembly according to claim 1 wherein the lower surface of said support structure contacts a substantially dielectric material positioned between said support structure and said mounting base.

12. The dual mode antenna assembly according to claim 1, further comprising a cover that contacts said mounting base and encloses said antenna structure.

13. The dual mode antenna assembly as according to claim 1 wherein the at least one cable element comprises:

a first cable, wherein the first cable is a signal feeding cable for said satellite element and connects to a first cable connector in said mounting base; and

a second cable, wherein the second cable is a signal feeding cable for said terrestrial element and connects to a second cable connector in said mounting base.

14. The dual mode antenna assembly according to claim 1 wherein the at least one cable has a first, a second, a third and a fourth lead portion extending therefrom, wherein:

the first lead portion connects to the satellite element;

the second lead portion connects to the terrestrial element;

the third lead portions connects to a first cable connector in said mounting base associated with the satellite element; and

said fourth lead portion connects to a second cable connector in said mounting base associated with the terrestrial element.

15. The dual mode antenna assembly according to claim 1 wherein the at least one cable is a single

cable that is connected to a cable connector in said mounting base, and wherein the single cable comprises first and second lead portions that connect to the satellite element and the terrestrial element, respectively.

16. A method of transmitting and/or receiving signals to/from a first communication device from/to a second communication device at least alternately via at least one of a terrestrial and a satellite communication system, using a dual mode antenna structure comprising a terrestrial element and a satellite element, wherein the satellite element comprises a core having four radiating elements disposed on a surface thereof, the core being positioned concentrically around and external to the terrestrial element, said method comprising the steps of:

a) providing a power source connecting to the satellite and terrestrial elements;

b) using the terrestrial element to transmit and/or receive radio signals;

c) using the satellite element to transmit and/or receive radio signals; and

d) providing an impedance matching network electrically connected to the terrestrial element such that the impedance of the terrestrial element located inside the satellite element has essentially the same impedance as that of an isolated terrestrial element not surrounded by the satellite element.

17. The method of transmitting according to claim 16 wherein the satellite element is driven by a quadrature combiner/splitter circuit.

18. The method of transmitting according to claim 17 wherein the impedance matching network functions such that the impedance of the terrestrial element when located inside the satellite element has substantially the same impedance as that of an isolated terrestrial element not surrounded by the satellite element.

19. The method of transmitting according to claim 16 wherein the impedance matching network functions such that the impedance of the terrestrial element when located inside the satellite element has substantially the same impedance as that of an isolated terrestrial element not surrounded by the satellite element.

20. The method of transmitting according to claim 16 wherein the core comprises a substantially dielectric material.

21. A method of assembling a dual mode antenna assembly for transmitting and/or receiving signals to/from a first communication device from/to a second communication device at least alternately via at

least one of a terrestrial and a satellite communication system, said multimode antenna assembly method comprising the steps of:

a) providing an antenna mounting base;

b) positioning a satellite antenna and a terrestrial antenna on the antenna mounting base, wherein the satellite element is positioned concentrically around and external to the terrestrial element;

c) providing a circuit board that isolates the desired signals to the respective satellite and terrestrial antennas;

d) attaching cables between the circuit board provided in step c) and a second circuit board used for receiving and/or transmitting RF signals to/from the satellite and/or terrestrial antennas;

e) providing a mounting base with at least one cable connector;

f) providing an electrical connection between impedance matching circuitry, the satellite antenna, and the terrestrial antenna; and

g) attaching at least one cable to the receive/transmit circuitry and the at least one cable connector.

22. The method of assembling as recited in claim 21 wherein the circuit board provided in step c) is mounted on the antenna mounting base.

23. The method of assembling as recited in claim 21 further comprising the step of:
h) securing a substantially dielectric material to an underside of the antenna mounting base.

24. The method of assembling as recited in claim 21 further comprising the step of:
i) placing a radome cover over the satellite and terrestrial antennas.

25. The method of assembling as recited in claim 24 further comprising the step of:
j) securing a clamping device to the radome enclosure and mounting base to form a substantially airtight connection therebetween.

26. The method of assembling as recited in claim 25 wherein the clamping device is a ring clamp.

27. The method of assembling as recited in claim 25 wherein the antenna mounting base has a slot formed near and disposed about its perimeter for housing a material that contacts the mounting base and the radome enclosure.

28. A dual mode antenna assembly for at least one of transmitting and receiving signals at least one of to and from a first communication device at least one of to and from a second communication device at least alternately via a terrestrial system and a satellite communication system, said dual mode antenna assembly comprising:
a terrestrial antenna element responsively communicable with the at least one of the first and second communication devices via the terrestrial system;
a satellite antenna element responsively communicable with the at least one of the first and second communication devices via the satellite system, said satellite antenna element positioned substantially concentrically around said terrestrial antenna element and of a substantially similar height;
at least first and second cable conductors connectable to the terrestrial and the satellite antenna elements, respectively;
an antenna base capable of supporting the satellite and terrestrial antenna elements; and
an optional antenna cover connectable to said antenna base.

29. A dual mode antenna assembly according to claim 28, wherein said satellite antenna element is

positioned substantially concentrically around said terrestrial antenna in a spiral configuration.

30. A dual mode antenna assembly according to claim 28, wherein said satellite antenna element is positioned substantially concentrically and helically around said terrestrial antenna in a spiral configuration.

31. A dual mode antenna assembly according to claim 28, further comprising a core element supported by said antenna base, wherein said satellite antenna element is wound around said core element in a spiral configuration.

32. A dual mode antenna assembly according to claim 31, wherein said core element comprises a substantially dielectric material.

33. A dual mode antenna assembly according to claim 31, further comprising a stabilizing element disposed between said core element and said terrestrial antenna element, and supporting said terrestrial antenna element.

34. A dual mode antenna assembly according to claim 33, wherein said stabilizing element comprises a substantially foam-like material.

AMENDED CLAIMS

[received by the International Bureau on 16 March 2001 (16.03.01); new claims 35-46 added; remaining claims unchanged (2 pages)]

35. A dual mode antenna assembly for transmitting and/or receiving signals to/from a first communication device from/to a second communication device at least alternately via at least one of a monopole terrestrial and a satellite communication system, said multimode antenna assembly comprising:

an antenna structure comprising: a monopole terrestrial element, and a helical satellite element; said satellite element being positioned substantially concentrically around and external to said terrestrial element;

an impedance matching circuit electrically connected to the terrestrial element;

a support structure supporting said antenna structure; and

a mounting base having an upper surface and a lower surface, wherein the lower surface contacts a surface to which said multimode antenna assembly is secured or substantially secured and wherein the upper surface supports said support structure, said mounting base having at least one cable connector to receive at least one cable element that is electrically connected to the satellite element and to the terrestrial element.

36. The method of transmitting according to claim 35 wherein the satellite element is driven by a quadrature combiner/splitter circuit.

37. The dual mode antenna assembly according to claim 35 wherein the terrestrial element operates at 800 MHz.

38. The dual mode antenna assembly according to claim 35 wherein said satellite element comprises a cylindrical core having four antenna elements disposed on a surface thereof.

39. The dual mode antenna assembly according to claim 35 wherein said cylindrical core comprises a substantially dielectric material.

40. The dual mode antenna assembly according to claim 35 wherein the antenna elements are helically wound and spaced at approximately ninety degrees with respect to each other.

41. The dual mode antenna assembly according to claim 40 wherein each of the antenna elements works against the other three, effectively setting up a field external to the cylindrical core.

42. The dual mode antenna assembly according to claim 40 wherein the impedance matching circuit functions such that the impedance of the terrestrial element when located inside the satellite element has substantially the same impedance as that of an isolated terrestrial element not surrounded by the satellite element.

43. The dual mode antenna assembly according to claim 35 wherein the impedance matching circuit functions such that the impedance of the terrestrial element when located inside the satellite element has substantially the same impedance as that of an isolated terrestrial element not surrounded by the satellite element.

44. The dual mode antenna assembly according to claim 35 wherein said support structure serves as a radio frequency (RF) shield.

45. The dual mode antenna assembly according to claim 35 wherein the lower surface of said support structure contacts a substantially dielectric material positioned between said support structure and said mounting base.

46. The dual mode antenna assembly according to claim 35, further comprising a cover that contacts said mounting base and encloses said antenna structure.

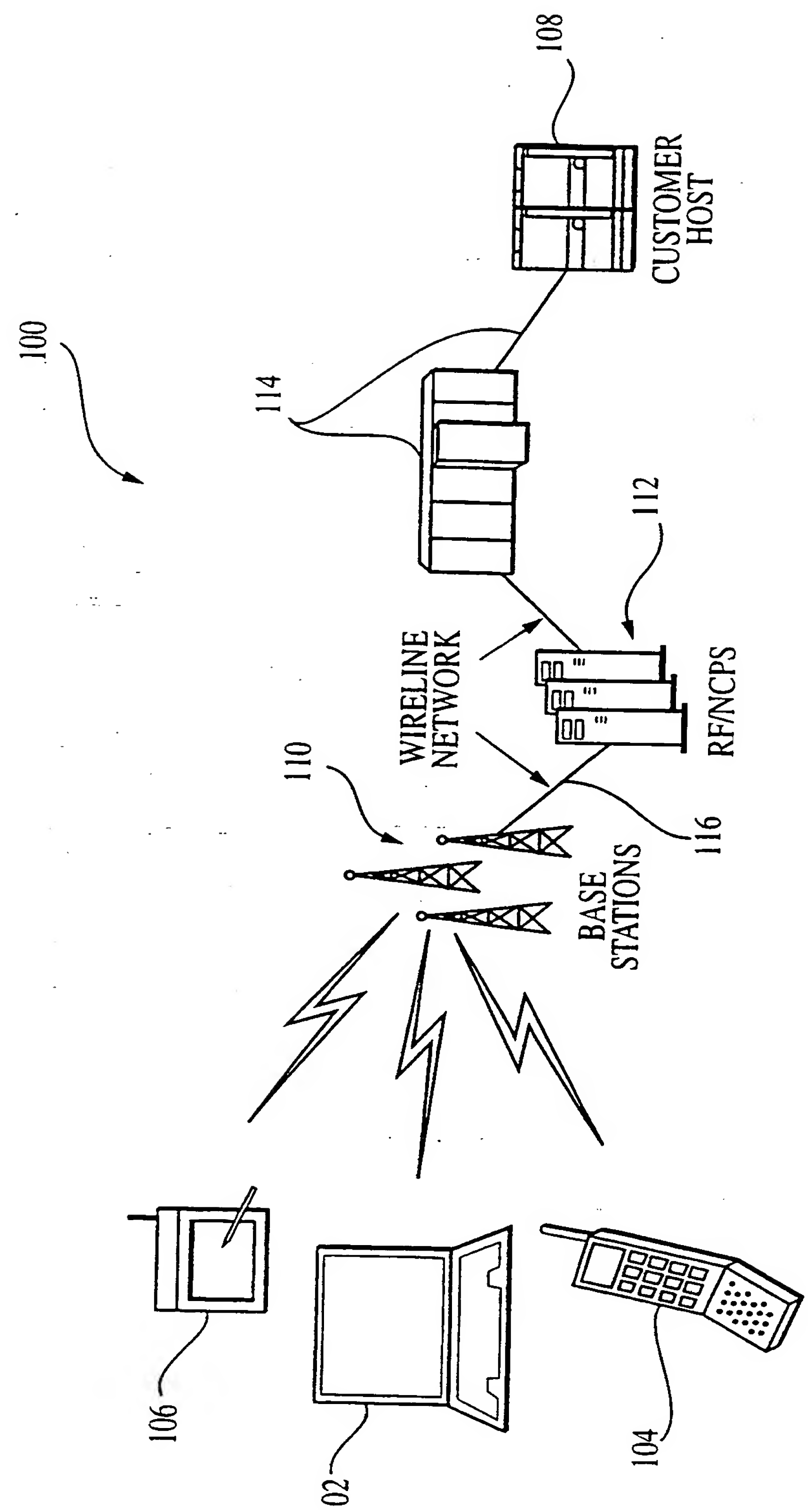

100
108
CUSTOMER
HOST
114
112
WIRELINE
NETWORK
RF/NCPS
110
116
BASE
STATIONS
106
102
104

FIG. 1

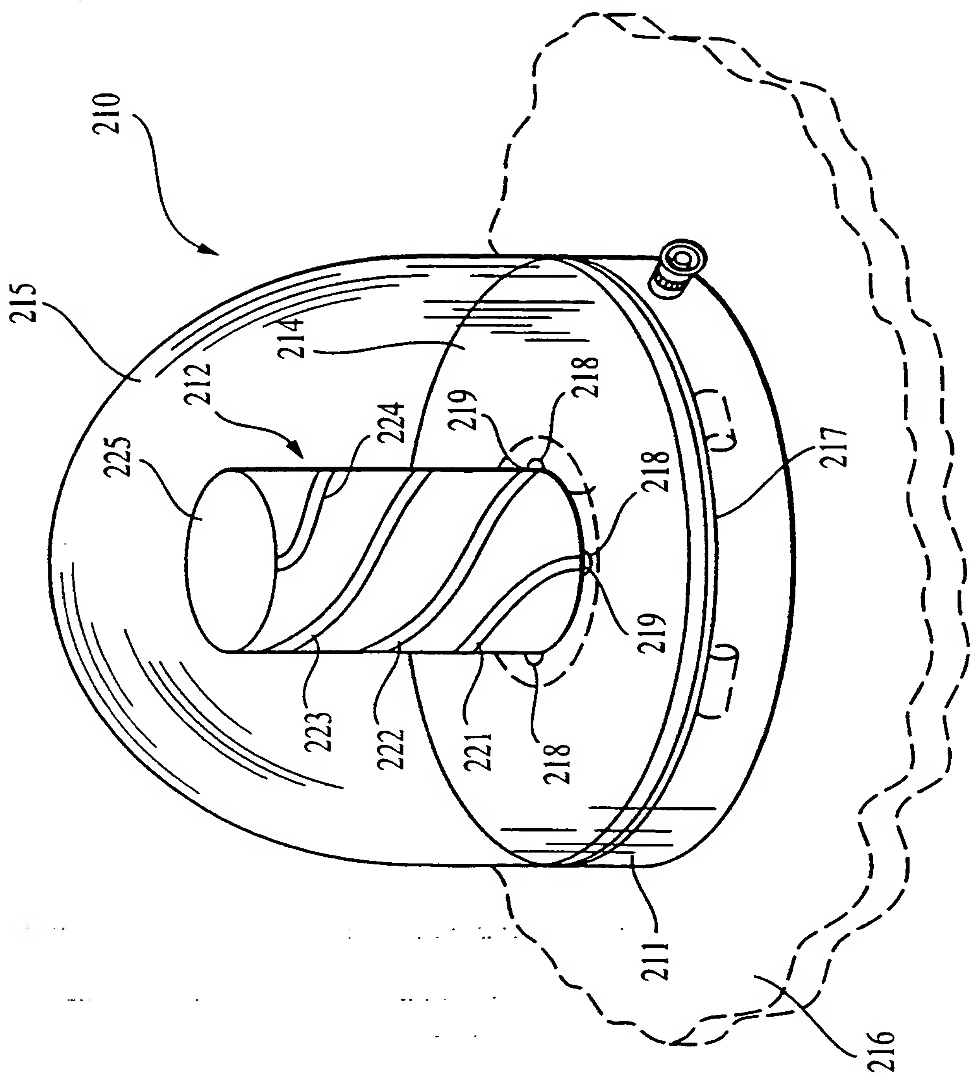


FIG. 2
PRIOR ART

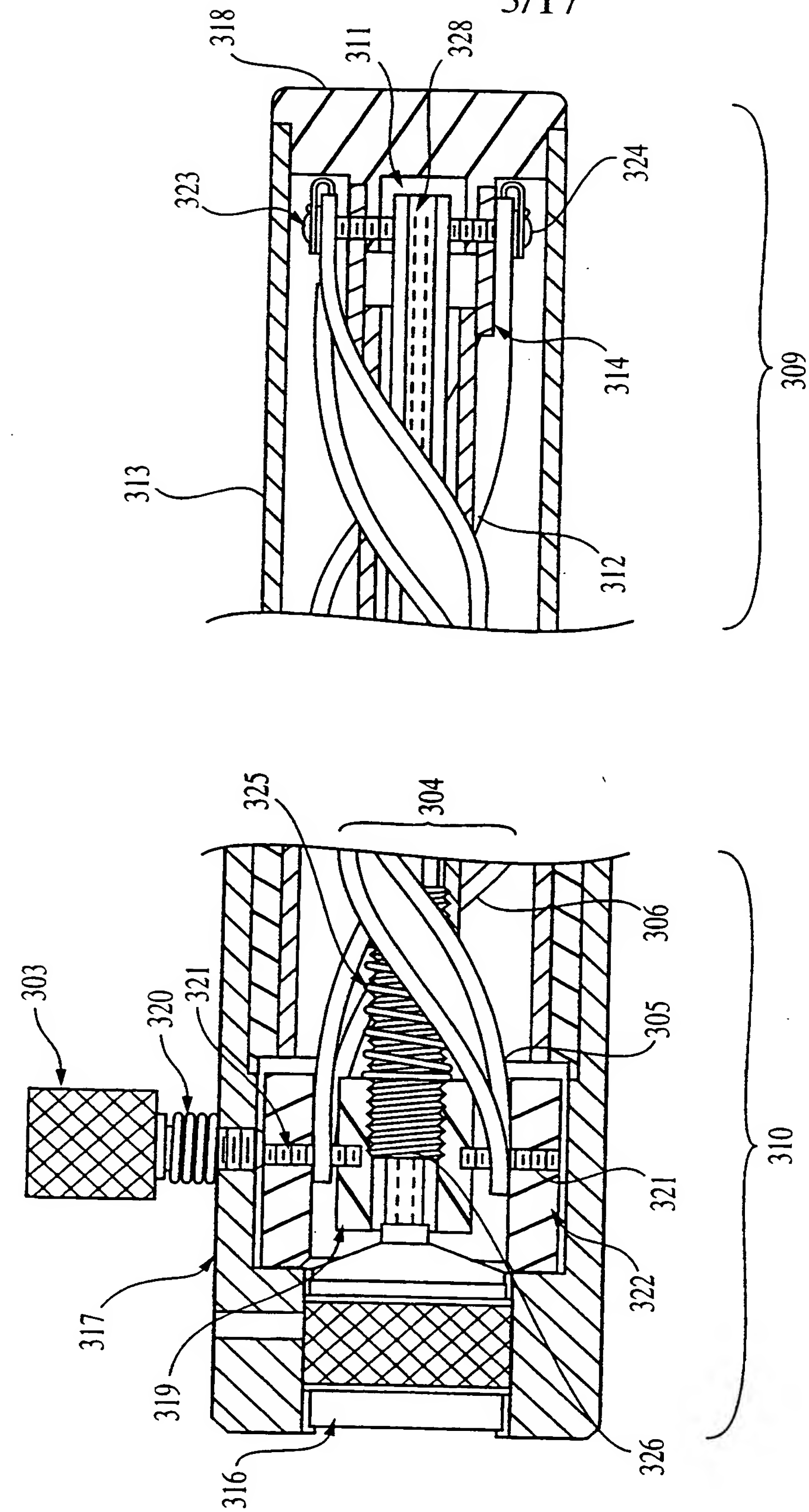
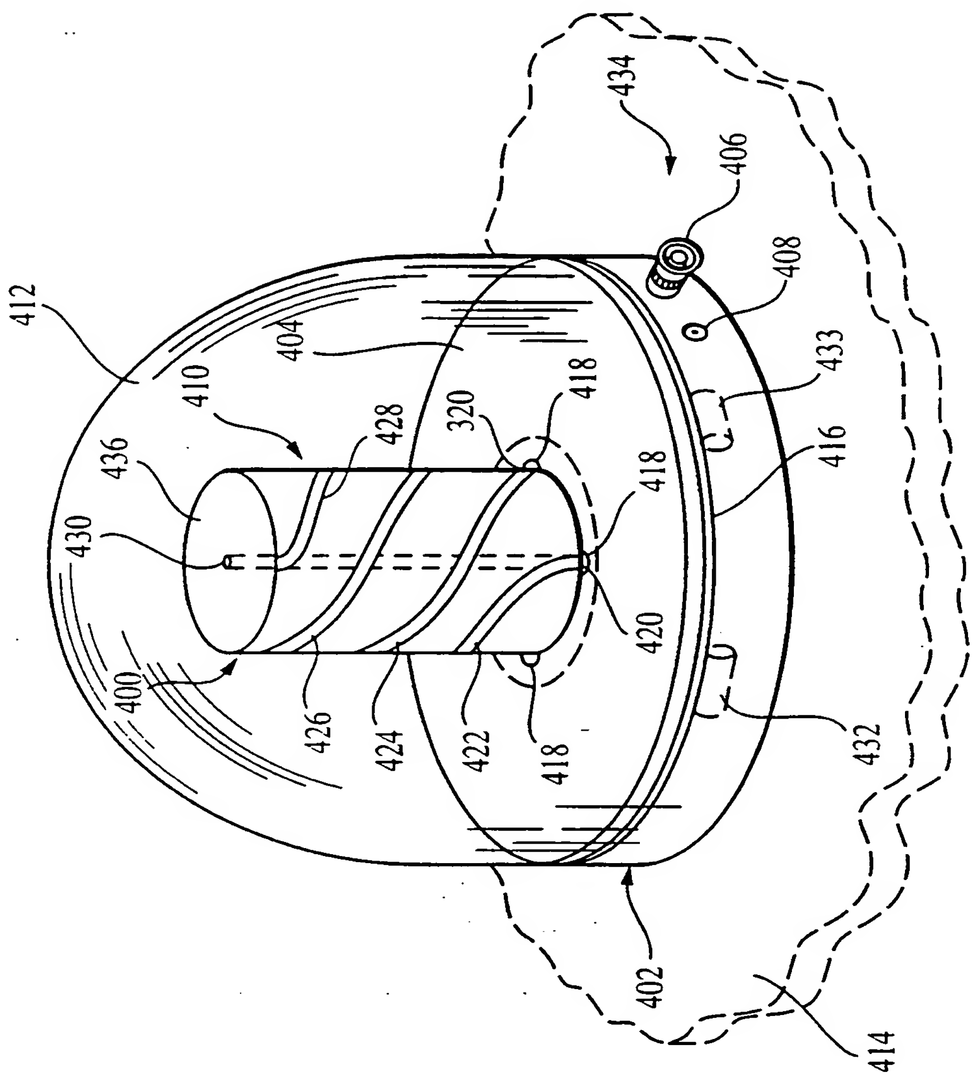


FIG. 3
PRIOR ART


434
406
408
412
404
433
410
418
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428
436
418
416
430
420
400
426
424
422
418
432
402
414

FIG. 4A

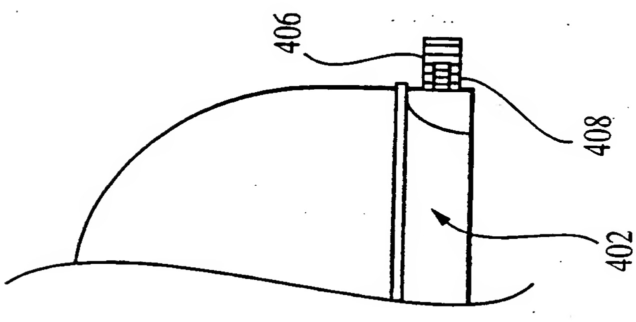


FIG. 4B

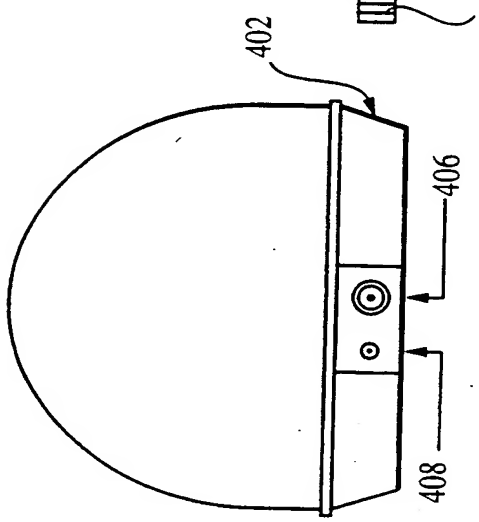


FIG. 4C

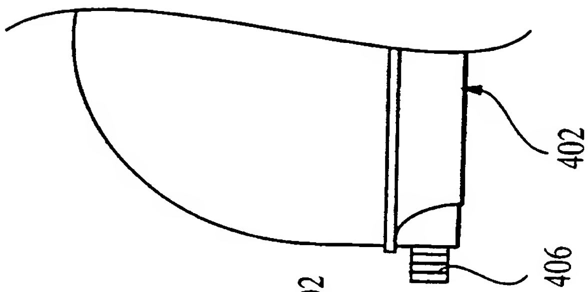


FIG. 4D

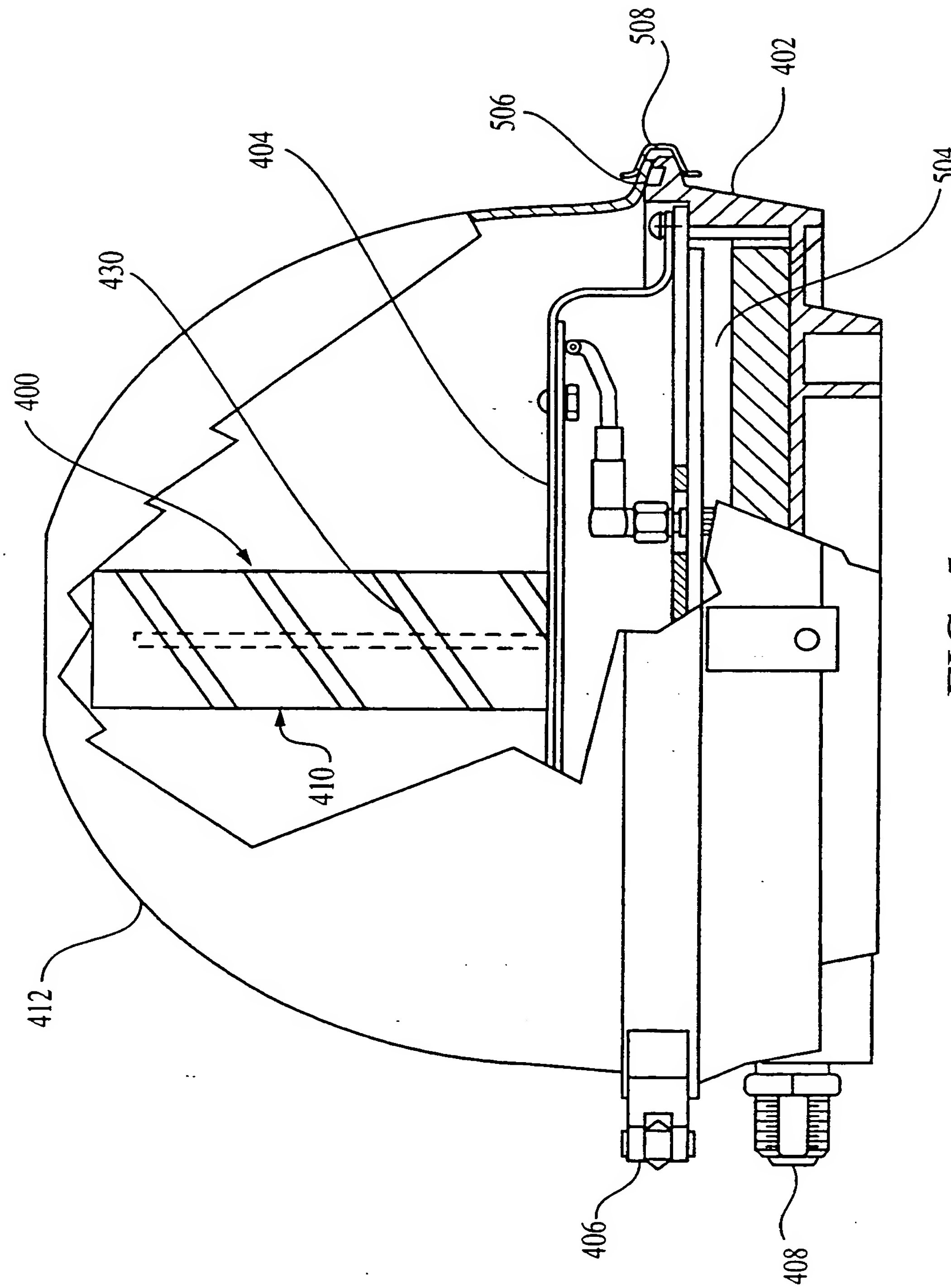


FIG. 5

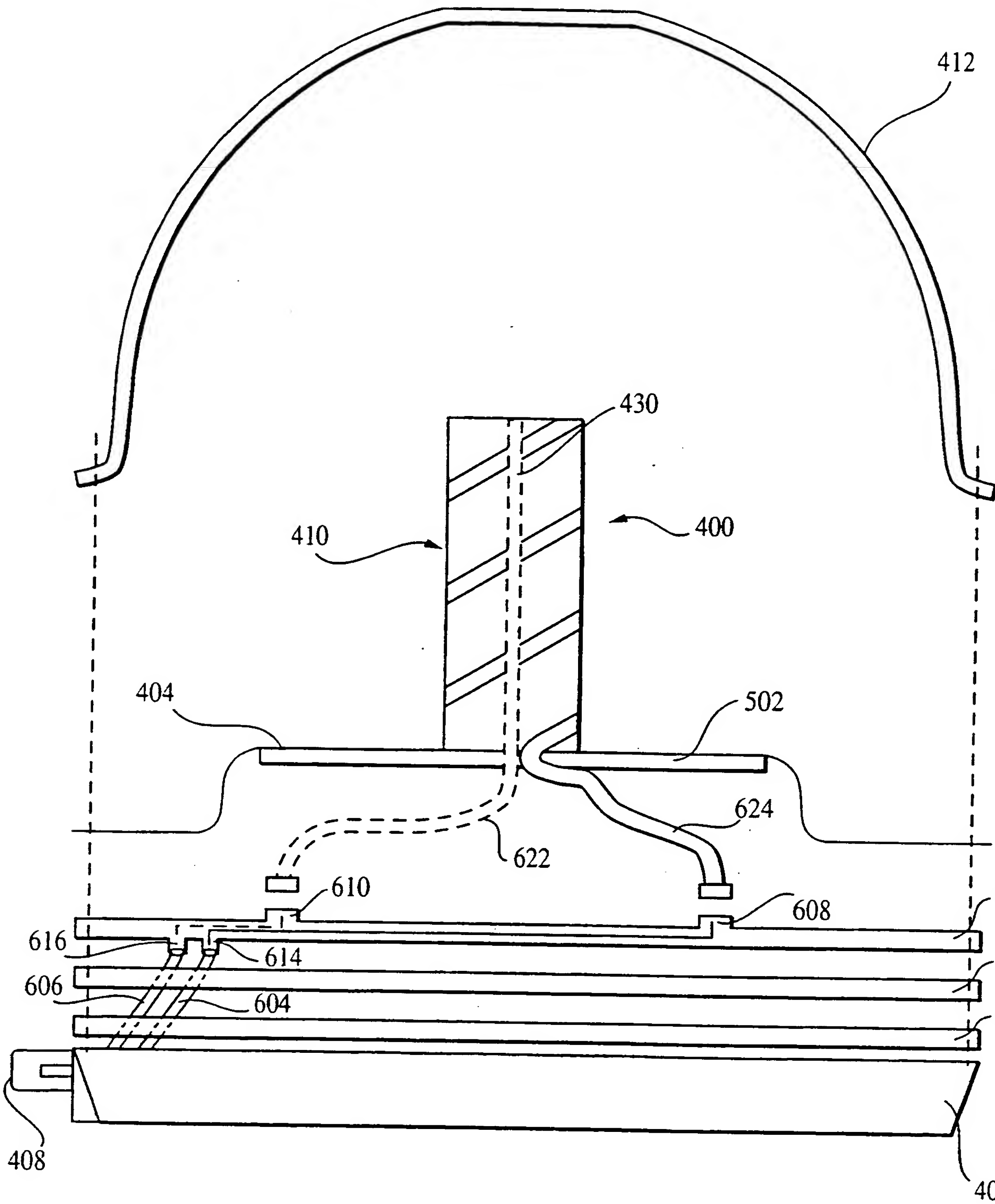
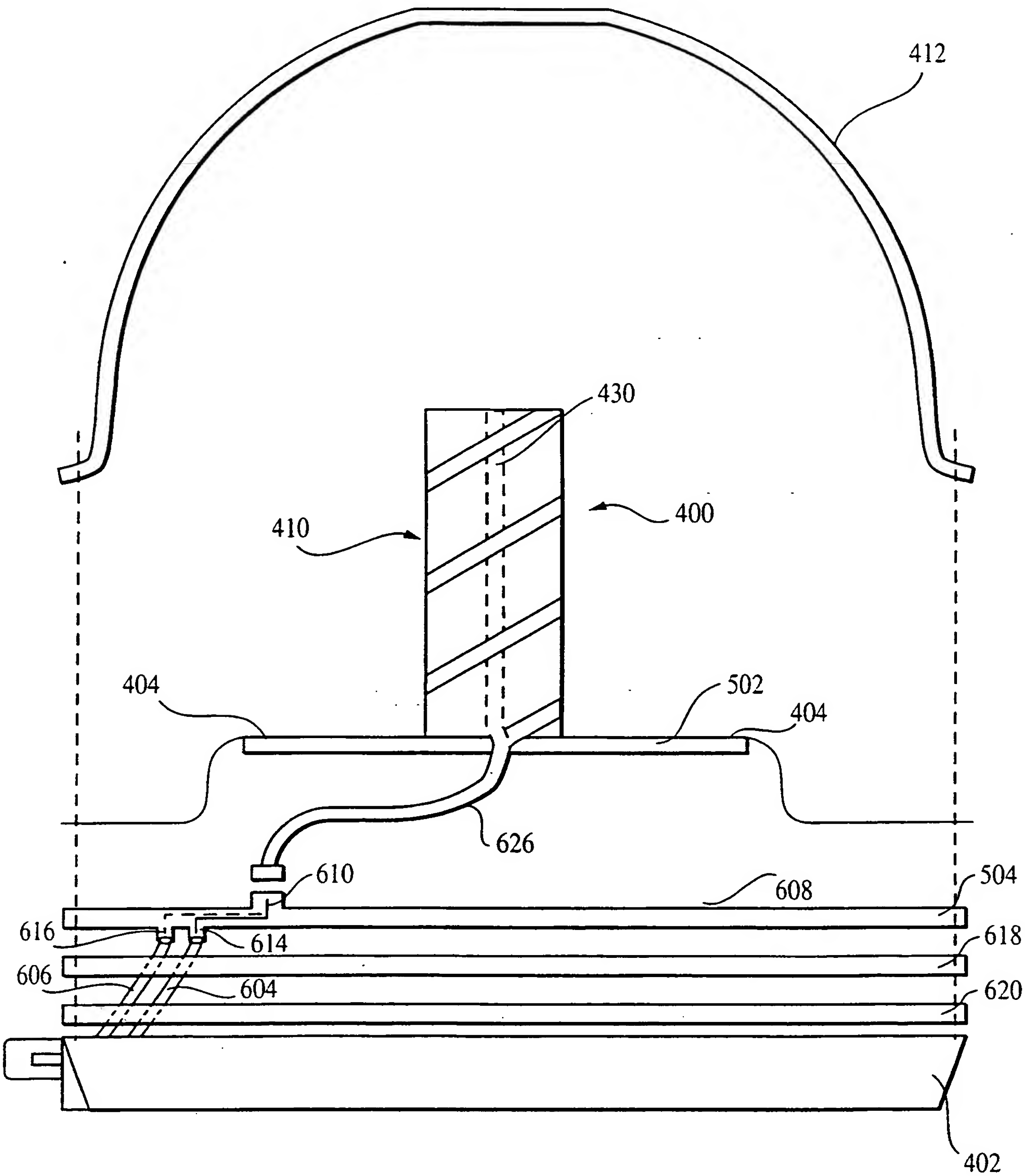

412
430
410
400
404
502
624
622
610
608
504
616
614
618
606
604
620
408
402

FIG. 6A



412
430
410
400
404
502
404
626
610
608
504
616
614
618
606
604
620
402

FIG. 6B

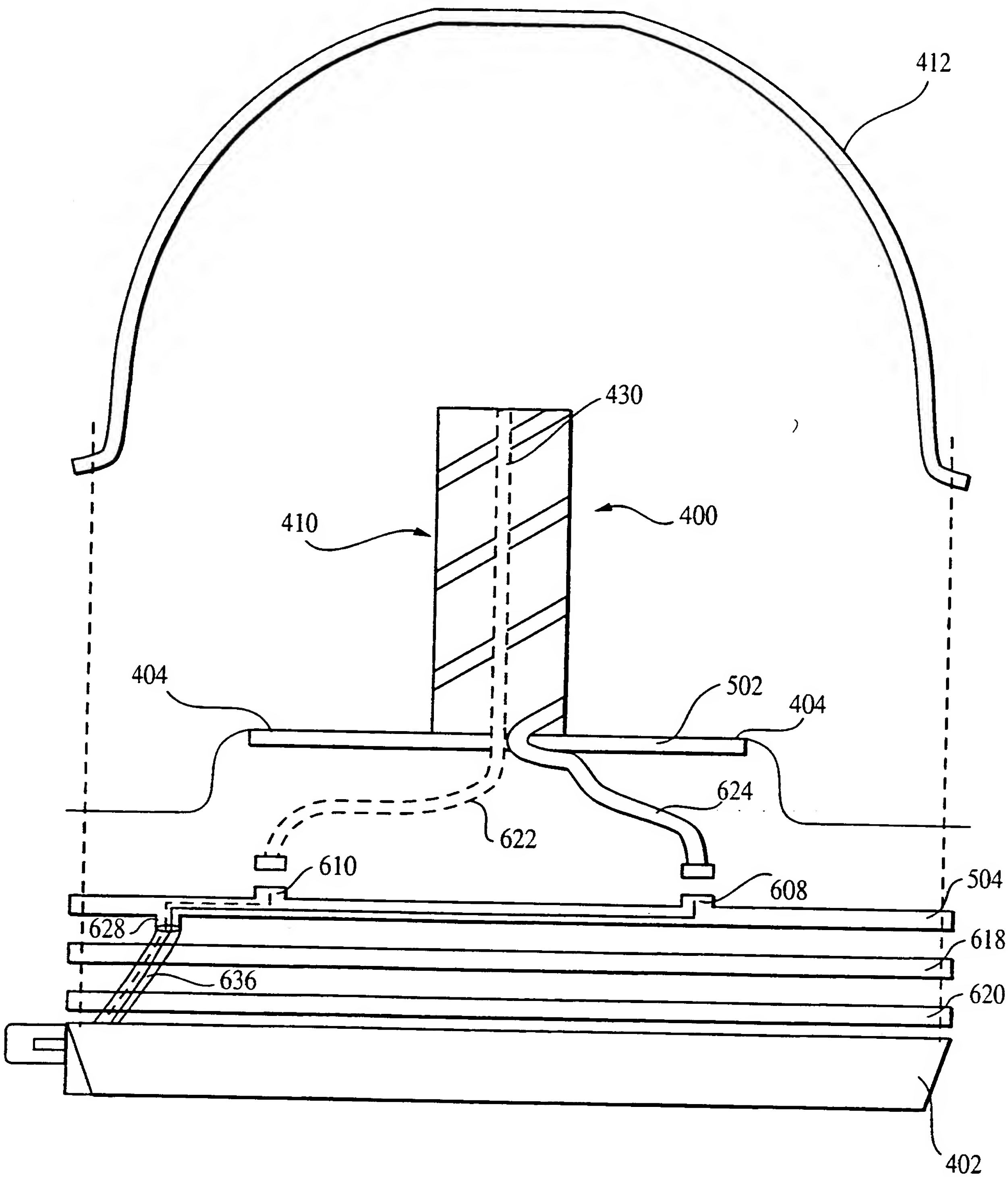

412
430
410
400
404
502
404
624
622
610
608
504
628
618
636
620
402

FIG. 6C

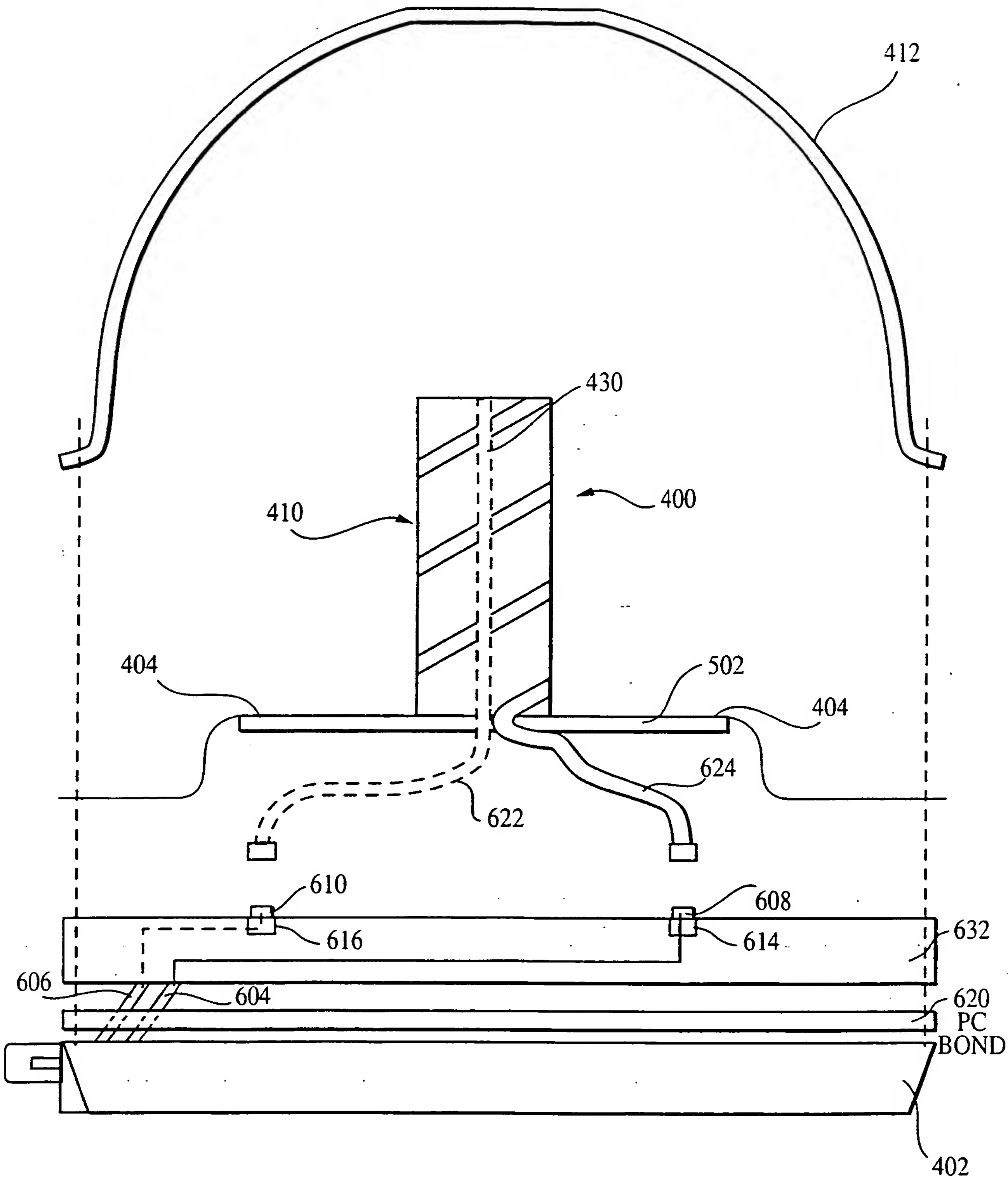

412
430
400
410
404
502
404
624
622
610
608
616
614
632
606
604
620
PC
BOND
402

FIG. 6D

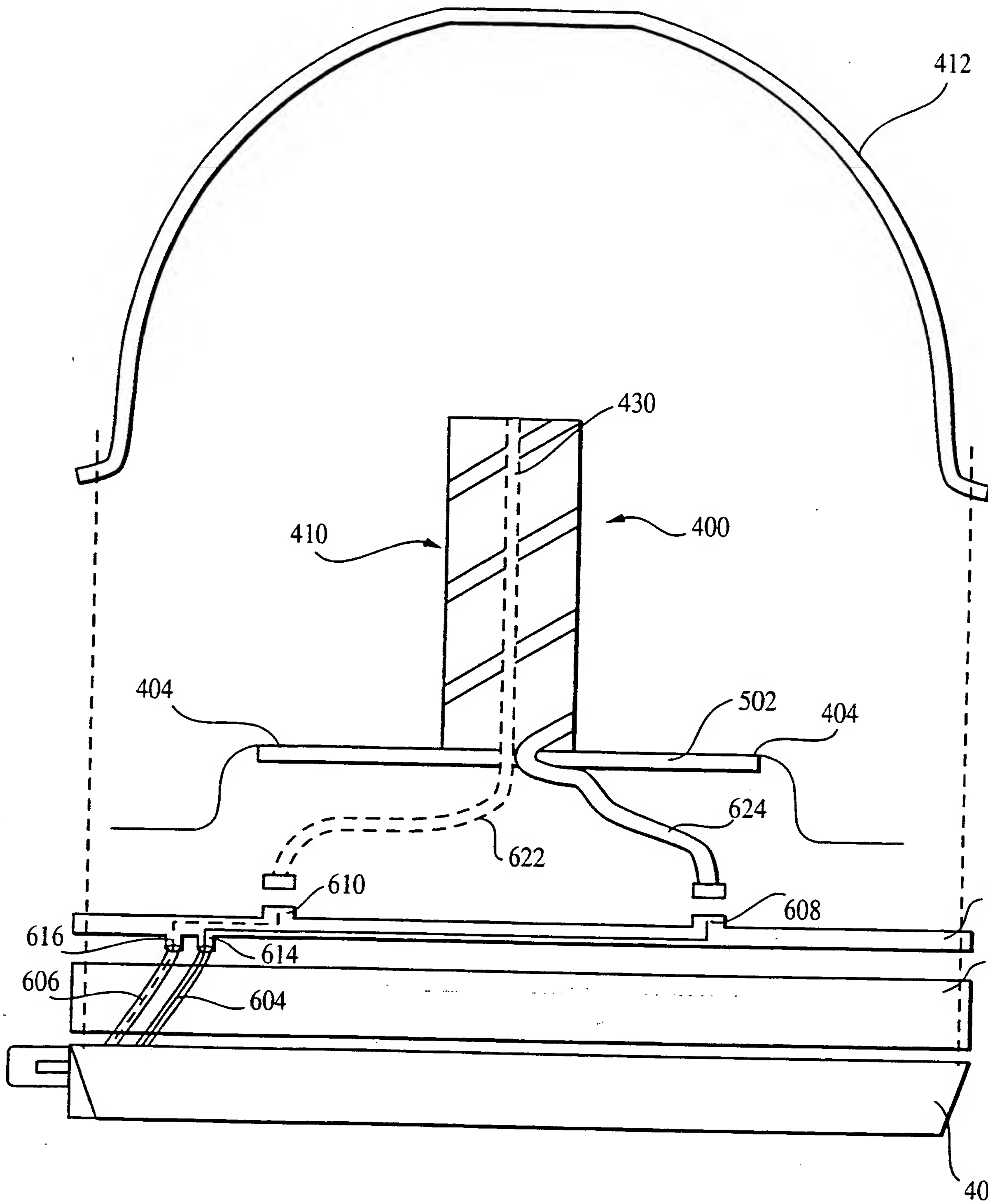

412
430
410
400
404
502
404
624
622
610
608
504
616
614
634
606
604
402

FIG. 6E

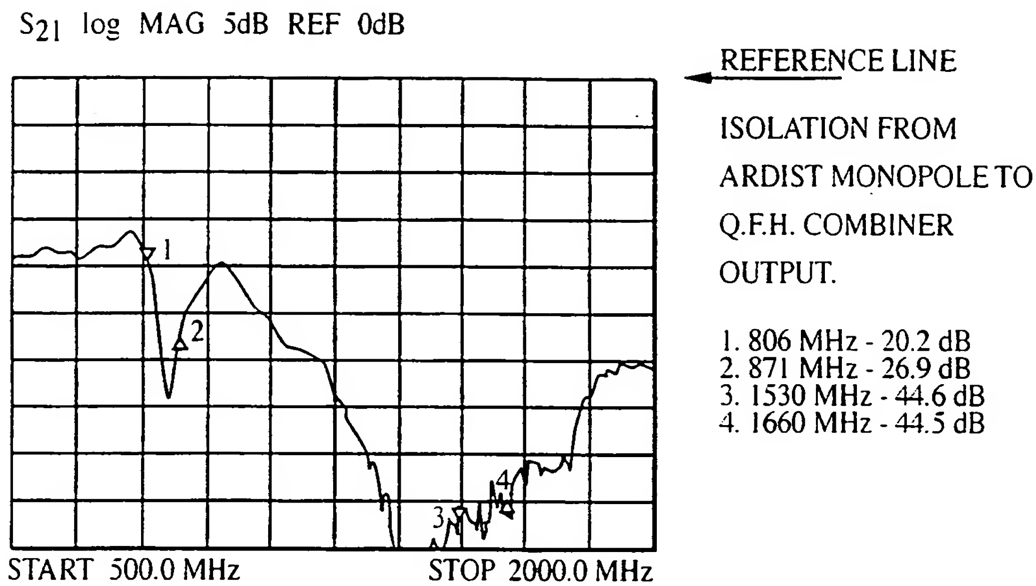

S21 log MAG 5dB REF 0dB
REFERENCE LINE
ISOLATION FROM
ARDIST MONOPOLE TO
Q.F.H. COMBINER
OUTPUT.
1. 806 MHz - 20.2 dB
2. 871 MHz - 26.9 dB
3. 1530 MHz - 44.6 dB
4. 1660 MHz - 44.5 dB
1
2
3
4
START 500.0 MHz
STOP 2000.0 MHz

FIG. 7

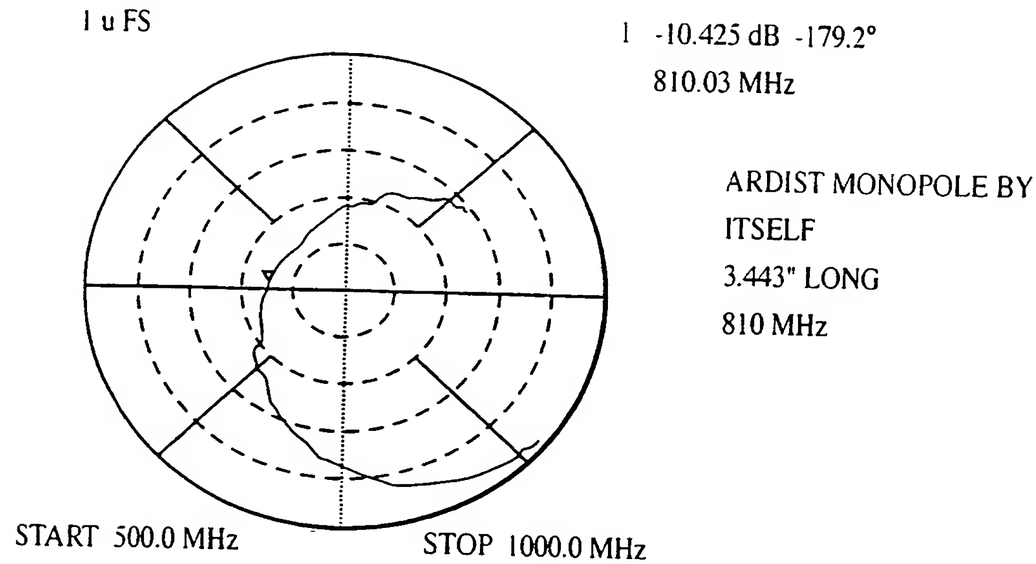

1 u FS
1 -10.425 dB -179.2°
810.03 MHz
ARDIST MONOPOLE BY
ITSELF
3.443" LONG
810 MHz
START 500.0 MHz
STOP 1000.0 MHz

FIG. 8A

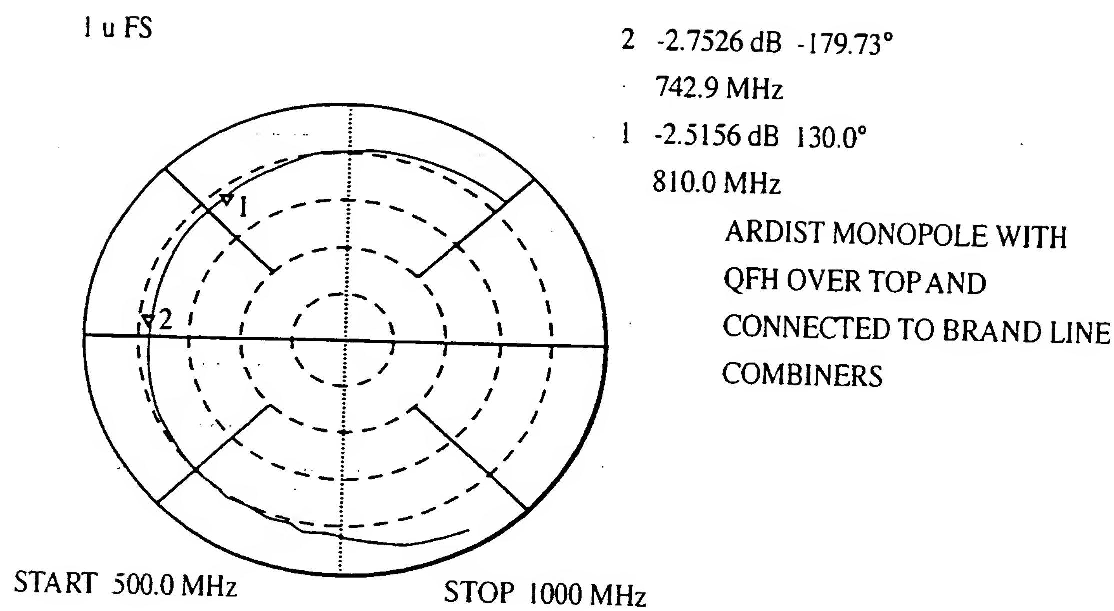

1 u FS
2 -2.7526 dB -179.73°
742.9 MHz
1 -2.5156 dB 130.0°
810.0 MHz
ARDIST MONOPOLE WITH
QFH OVER TOP AND
CONNECTED TO BRAND LINE
COMBINERS
1
2
START 500.0 MHz
STOP 1000 MHz

FIG. 8B

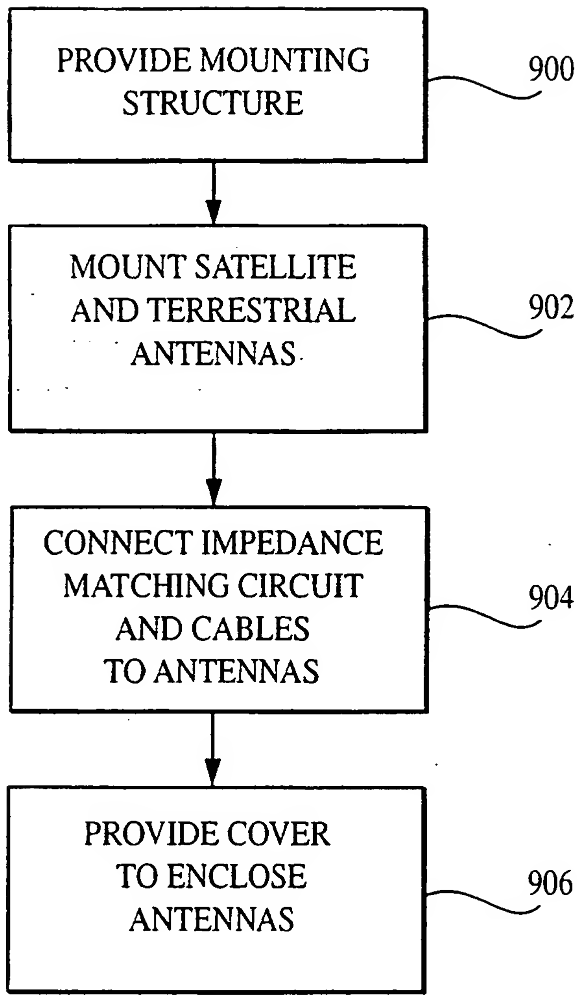

PROVIDE MOUNTING STRUCTURE
900
MOUNT SATELLITE AND TERRESTRIAL ANTENNAS
902
CONNECT IMPEDANCE MATCHING CIRCUIT AND CABLES TO ANTENNAS
904
PROVIDE COVER TO ENCLOSE ANTENNAS
906

FIG. 9A

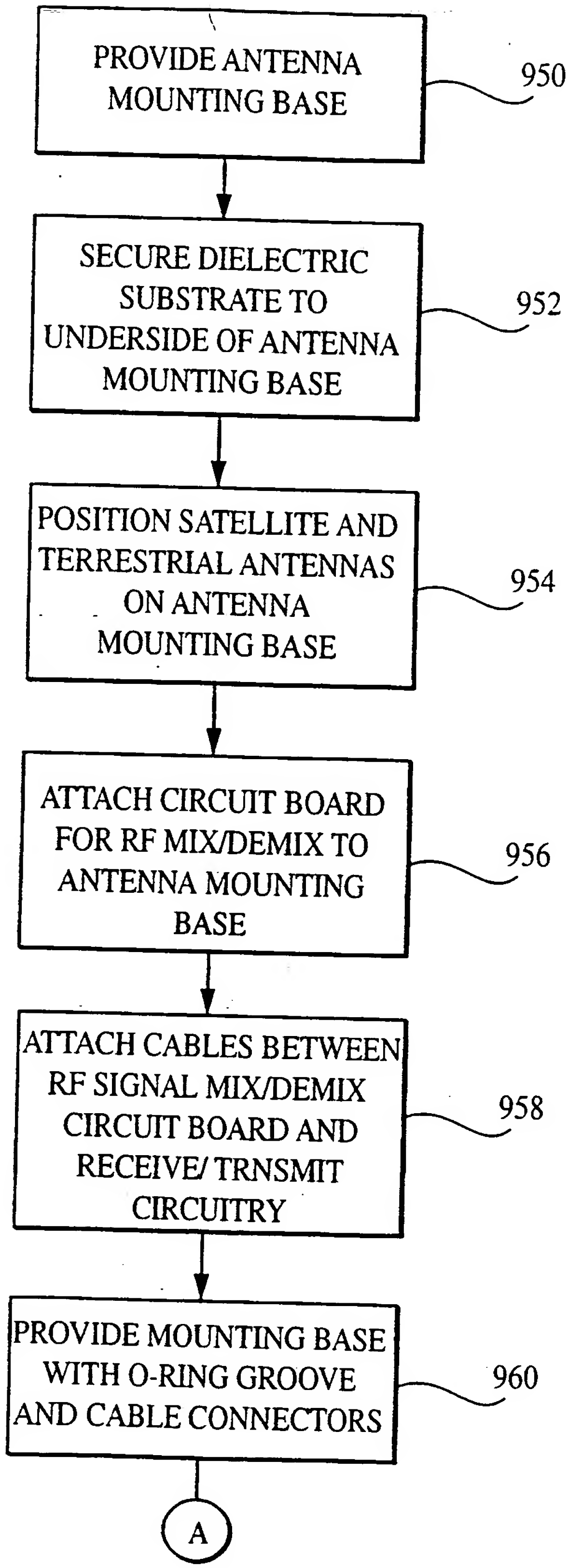

PROVIDE ANTENNA MOUNTING BASE
950
SECURE DIELECTRIC SUBSTRATE TO UNDERSIDE OF ANTENNA MOUNTING BASE
952
POSITION SATELLITE AND TERRESTRIAL ANTENNAS ON ANTENNA MOUNTING BASE
954
ATTACH CIRCUIT BOARD FOR RF MIX/DEMIX TO ANTENNA MOUNTING BASE
956
ATTACH CABLES BETWEEN RF SIGNAL MIX/DEMIX CIRCUIT BOARD AND RECEIVE/ TRNSMIT CIRCUITRY
958
PROVIDE MOUNTING BASE WITH O-RING GROOVE AND CABLE CONNECTORS
960
A

FIG. 9B

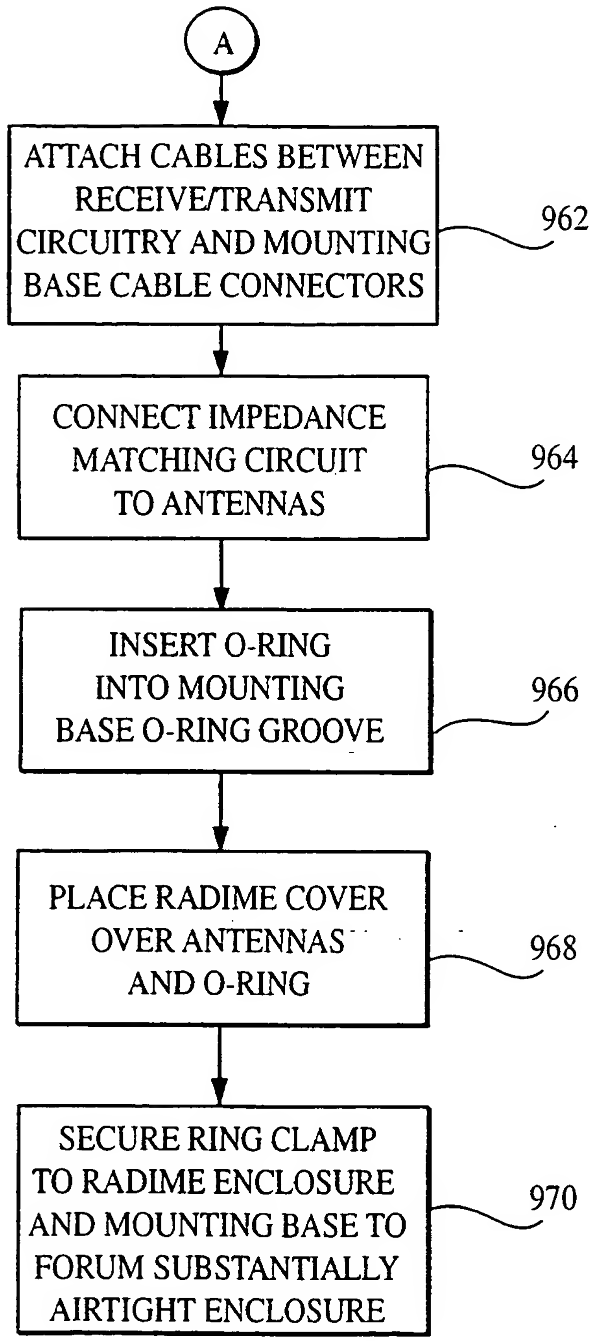

A
ATTACH CABLES BETWEEN RECEIVE/TRANSMIT CIRCUITRY AND MOUNTING BASE CABLE CONNECTORS
962
CONNECT IMPEDANCE MATCHING CIRCUIT TO ANTENNAS
964
INSERT O-RING INTO MOUNTING BASE O-RING GROOVE
966
PLACE RADIME COVER OVER ANTENNAS AND O-RING
968
SECURE RING CLAMP TO RADIME ENCLOSURE AND MOUNTING BASE TO FORUM SUBSTANTIALLY AIRTIGHT ENCLOSURE
970

FIG. 9B

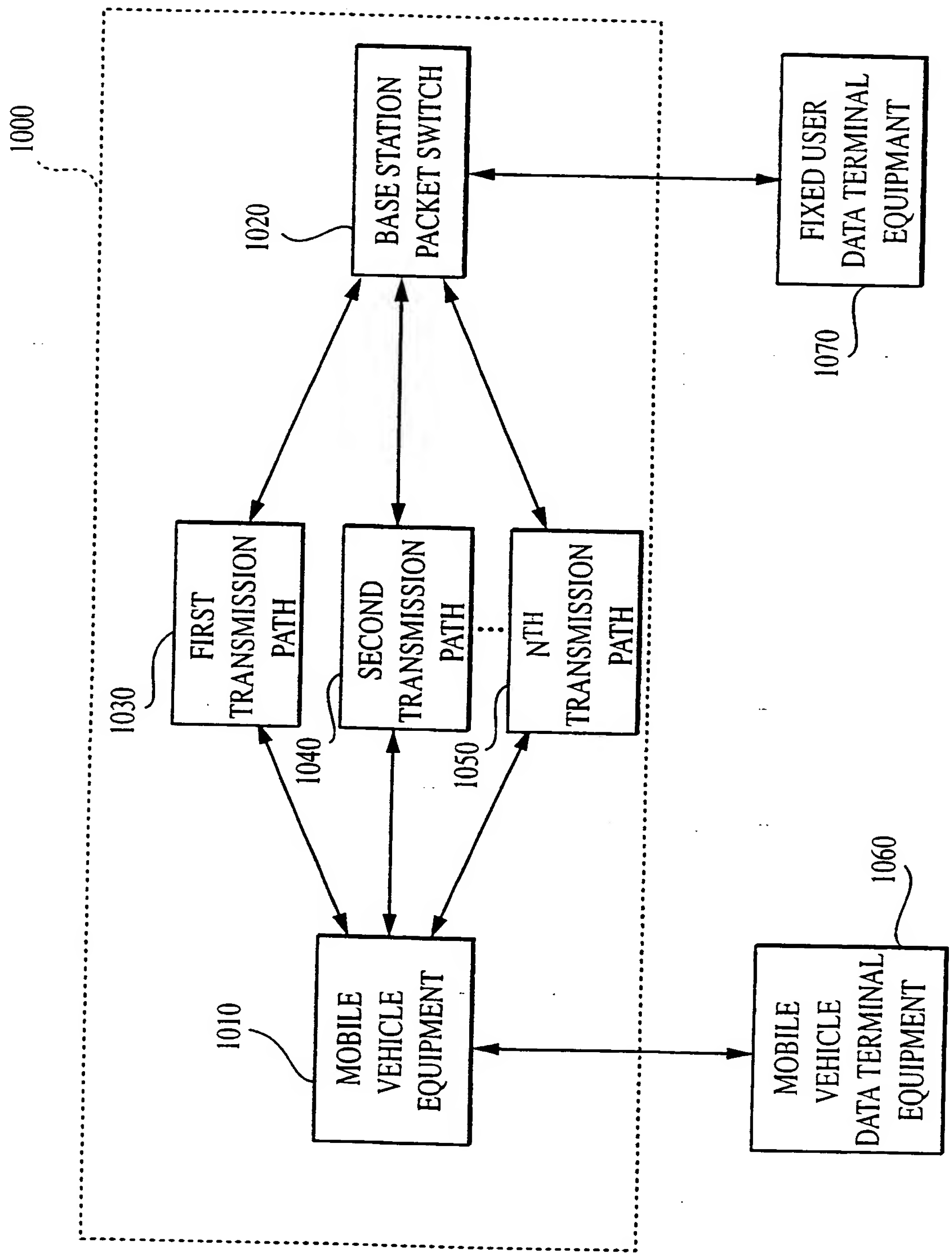

1000
BASE STATION
PACKET SWITCH
1020
FIXED USER
DATA TERMINAL
EQUIPMANT
1070
FIRST
TRANSMISSION
PATH
1030
SECOND
TRANSMISSION
PATH
1040
NTH
TRANSMISSION
PATH
1050
MOBILE
VEHICLE
EQUIPMENT
1010
MOBILE
VEHICLE
DATA TERMINAL
EQUIPMENT
1060

FIG. 10

INTERNATIONAL SEARCH REPORT	International application No. PCT/US00/29288

A. CLASSIFICATION OF SUBJECT MATTER

IPC(7) :H01Q 1/36, 1/38, 1/24
US CL :Please See Extra Sheet.
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 343/700MS, 725, 785, 829, 729, 785, 727, 895, 702; 333/219.1, 126, 134; 370/37, 281, 295, 297

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

NONE

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

NONE

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5,963,180 A (LEISTEN) 05 October 1999 (05.10.2000), entire document.	1-15 28-34
Y	US 6,133,891 A (JOSYPENKO) 17 October 2000 (17.10.2000), entire document.	1-15 28-34
Y	US 6,025,816 A (DENT et al) 15 February 2000 (15.02.2000), entire document.	1-34
Y	US 6,147,647 A (TASSOUDJI et al) 14 November 2000 (14.11.2000), entire document.	16-27

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"A" document defining the general state of the art which is not considered to be of particular relevance	"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"E" earlier document published on or after the international filing date	
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"O" document referring to an oral disclosure, use, exhibition or other means	
"P" document published prior to the international filing date but later than the priority date claimed	"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
08 DECEMBER 2000	17 JAN 2001
Name and mailing address of the ISA/US Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231 Facsimile No. (703) 305-3230	Authorized officer Shawn S. Hoppe CHUC TRAN Telephone No. (703) 306-5984

Form PCT/ISA/210 (second sheet) (July 1998) ★

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US00/29288

A. CLASSIFICATION OF SUBJECT MATTER:
US CL :

343/700MS, 725, 785, 829, 729, 785, 727, 895, 702; 333/219.1, 126, 134; 370/37, 281, 295, 297